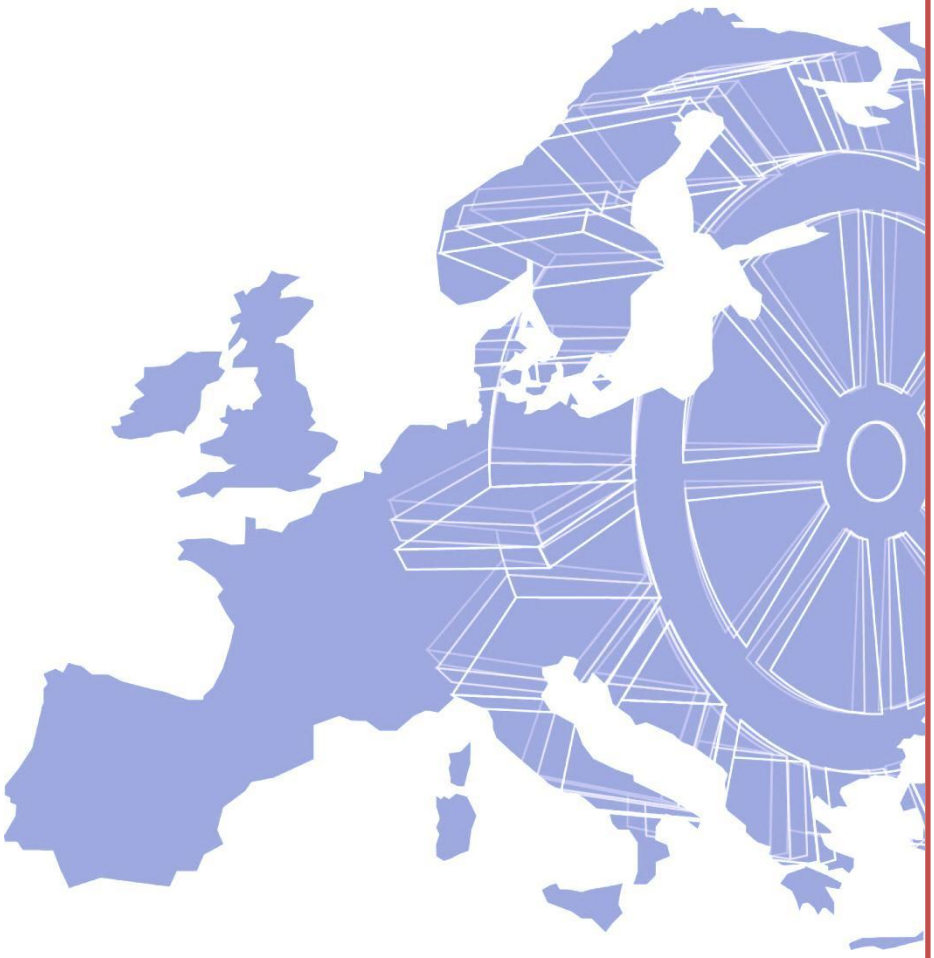
RESTOR HYDRO



Small and Micro Hydropower Restoration Handbook

The All-Inclusive Replicable Model

Permalink: http://www.restor-hydro.eu/

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European Small Hydropower Association (ESHA)

Co-funded by the Intelligent Energy Europe Programme of the European Union

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Introduction

RESTOR Hydro is a project, supported by the Intelligent Energy Europe (IEE) programme from the European Commission, aiming at increasing renewable energy production from small and micro hydropower, by identifying and restoring suitable historical sites, mills and hydropower stations that are currently inoperative. 350,000 sites are estimated to be abandoned and could be brought back on line.

The objective of this handbook is to give all necessary tools and information needed for the refurbishment of potential small hydropower sites (water wheels, mills, weirs, existing barrages, etc.). The main output of this handbook resulted in an "all-inclusive replicable model". This handbook is containing a complete set of guidelines and tools necessary for refurbishing potential hydropower sites in eight countries (Belgium, France, Greece, Italy, Lithuania, Poland, Slovenia and Sweden) which can easily be replicated throughout the EU-28 Member States.

This publication covers key information on three topics.

1. Detailed information on the technical **permitting process** aiming at reducing the perceived financial risk of the unknown requirements that may stop, delay or derail a project.
2. Best **technical options** for the refurbishment of historical waterwheels/weirs are defined together with information on civil and environmental engineering, electrical and mechanical engineering, operations and maintenance. Best environmental solutions will be proposed.
3. Comprehensive information describing **how to fund small and micro hydro-power**. Different funding options are explored and analyses of benefits and risks are presented.

Chapter 1

Permitting

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1. Permitting

1.1. Introduction

The following chapter of this handbook outlines the process to follow in order to obtain permits for small hydropower (SHP) development in Greece, Belgium (both the Flemish and Walloon regions), Poland, France, Italy, Lithuania, Slovenia and Sweden. The document outlines the general processes for each country by giving guidance on the environmental regulations to follow and the authorisation documents needed (if any). Further detail is provided on how and where to obtain them along with the estimated duration period and cost implied. Collecting information on the administrative procedures of the eight target regions will reduce the perceived financial risk of unknown requirements which may otherwise stop, delay or derail a project. Information on the permitting procedure (rights to operate, environmental assessments needed and historical reviews and clearances), potential bottlenecks, and the length of time taken to receive a license will be examined in detail. Existing examples of best practices for simplifying permitting procedures in the EU member states will be reviewed and assessed for possible use in each target region.

This chapter aims to serve as a focused technical implementation by showing in detail how a targeted site or deliverables should be presented. Although it may not be 100% replicable, it intends to provide a template and a re-usable document such that the target audience can adopt, adapt and modify in order to best fit practices in their region.

1.2. Obtaining Permits for Small Hydropower Plants in Belgium

1.2.1. Flanders

Obtaining a permit for a SHP plant in Flanders used to be similar to the procedure in Wallonia. However, since the competences on this matter have shifted completely to the regional level decades ago, differences have inevitably appeared.

Like in Wallonia, the procedure differs according to the classification of the waterway:

a. Navigable waterways (streams, larger rivers and canals) fall under one of the two semi-public bodies: either mostly large rivers and canals (*Waterwegen en Zeekanaal nv*) or the Albert Canal and neighbouring canals (*De Scheepvaart nv*). These bodies are in charge of issuing a concession which allows the claimer to use of part of the water and waterway. To be able to issue this concession they need a positive advice from the Administration Responsible for Fish Migration (*Departement Leefmilieu, Natuur en Energie*, LNE). In addition to this, a building permit is required from the Department of the Flemish Region Responsible for Urbanism (*Ruimte Vlaanderen*). An environmental permit issued by the province where the project is built might also be necessary if the project ranges between 100 kW and 5 MW. Smaller projects only have to notify to the municipality about the fact

that a SHP smaller than 100 kW will start to operate. In terms of potential, Flanders offers some possibilities on navigable rivers and canals near the sluices. The highest potential is certainly found in the Albert Canal which presents several sluices with a head of about 10 meters. For this canal, the semi-public body itself is responsible for the development of the hydropower sites. In Flanders, waters (*waterrecht*) on the navigable rivers that date back to the *Ancien Régime* are not subject to private rights for their utilisation.

b. Non-navigable rivers category 1 (medium rivers) fall under the authority of the Flemish Environment Agency Department for Operational Water (*Vlaamse Milieu Maatschappij, afdeling Operationeel waterbeheer*, VMM). In fact, there is a huge difficulty in acquiring a concession for a SHP pant from the administration mentioned earlier unless it happens to be linked to an already existing sluice or historical watermill site which existence in the *Ancien Régime* can be proved. In the advent of this happening and only when nothing has been changed in the configuration of the site; no permits are needed, nor can the administration claim part of the water for a fish migration bypass. If changes have been made, then the procedure would be similar to 1. All three, an authorisation, building permit and environmental permit will be required for sites above 100 kW. In these cases the VMM will ask in its authorisation up to 50% of the water in order to solve fish migration issues.

c. Non-navigable rivers category 2 (small rivers) fall under the authority of the province where the project is located. The procedure would be similar to 2.

d. Non-navigable rivers category 3 (smallest rivers) fall under the authority of the municipality where the site is located. The procedure would be similar to 2.

Connection to the grid

In Flanders, it is necessary to make a contract with the local distribution operator (DNB) in order to establish the connection of a production site to the grid. The connection differs technically and in costs depending on the installed capacity, voltage (low and high) and production. For further detail please visit http://www.vreg.be/sites/default/files/uploads/trde_versie_15_mei_2012.pdf. Concretely, connection costs depend on the voltage level, the connection post and the type of connection. For further information about tariffs please visit http://www.creg.be/.

Several key steps apply around the necessary guidelines to follow when organising and applying for the several permits required for the development of SHP plants in Belgium. The below guidelines cover the full range of them going from the first stages of land procurement to the latter ones when connecting the finished plant to the national grid network.

The first stage requires the receipt of either or potentially two permits depending on the location of the potential site. When the site is located on public domain (land owned by

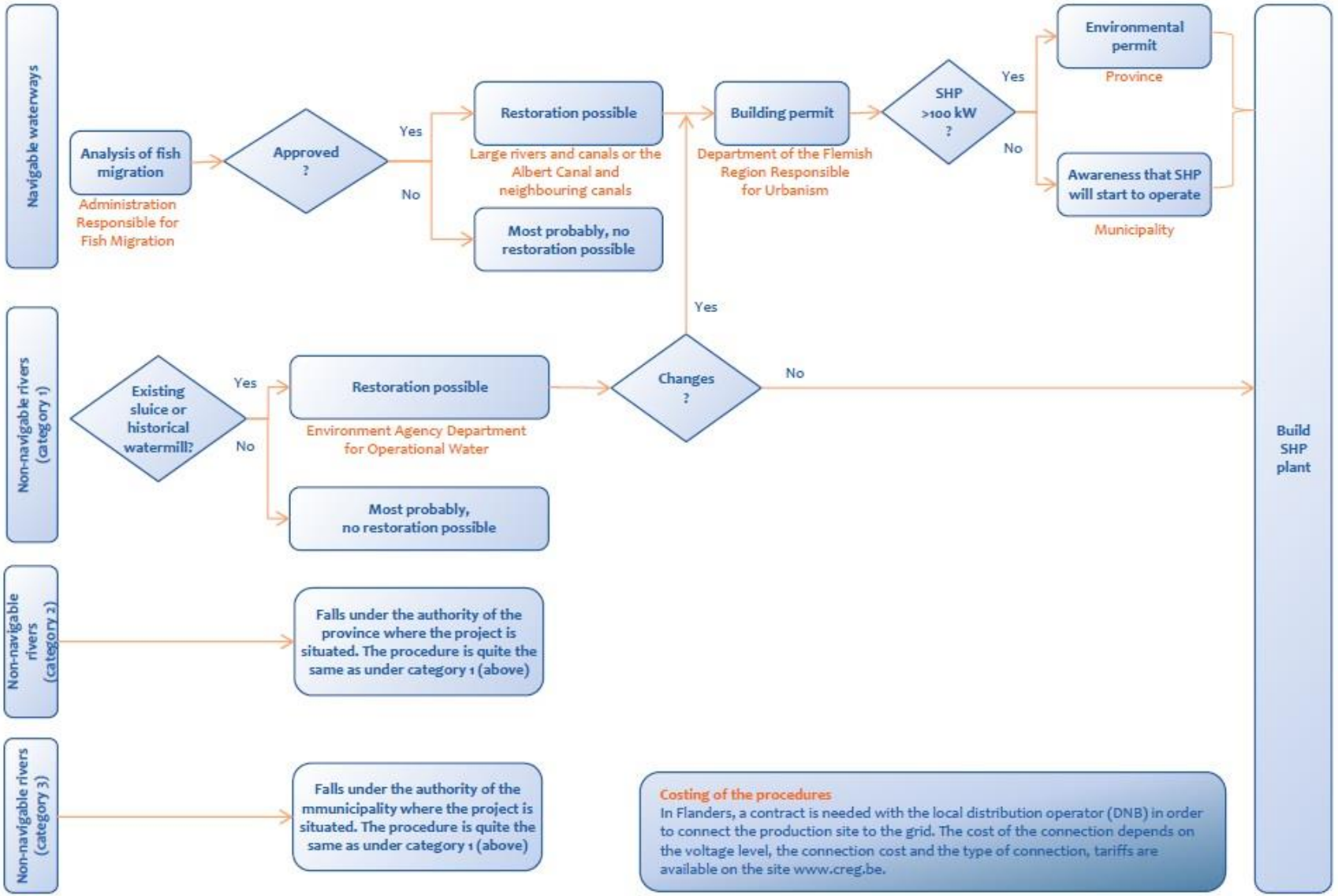
the public authorities of the Navigable Waterways Department), a concession or authorisation delivered by the same administration is requested. If the site is located on the private domain (mainly private owners, typically of old mills) a *droit d'eau* would be needed in order to proceed.

The next permit or permits required are either the water take authorisation (for navigable waterways) and/or the authorisation for modifying a watercourse (for non-navigable waterways) which are delivered by the Ministry of the Environment from the Non-navigable Waterways Department. While both permits are free of charge, the time taken to complete them is usually unknown as the legislation does not contemplate it.

An environmental permit is mandatory for every plant with a potential power output above 100 kW. This permit is reviewed and delivered on a case-by-case basis for each specific project. The time required to receive it usually takes between 160 to 190 days and there are no applicable charges for its delivery. It is important to note that new legislation is under preparation resulting on all plants, including those from 0 to 100 kW, being subject of having to apply for an environmental permit, although no changes have been decided to date.

Lastly a connection contract with the distribution or transport network operator is needed in order to enable the injection of the electricity to the grid. This procedure has both a variable cost and time taken as it fluctuates with the amount of installed capacity.

Belgian Permit process for SHP (Flanders)


Navigable waterways
Analysis of fish migration
Administration Responsible for Fish Migration
Approved ?
Yes
No
Restoration possible
Large rivers and canals or the Albert Canal and neighbouring canals
Most probably, no restoration possible
Building permit
Department of the Flemish Region Responsible for Urbanism
SHP >100 kW ?
Yes
No
Environmental permit
Province
Awareness that SHP will start to operate
Municipality
Non-navigable rivers (category 1)
Existing sluice or historical watermill?
Yes
No
Restoration possible
Environment Agency Department for Operational Water
Most probably, no restoration possible
Changes ?
Yes
No
Non-navigable rivers (category 2)
Falls under the authority of the province where the project is situated. The procedure is quite the same as under category 1 (above)
Non-navigable rivers (category 3)
Falls under the authority of the mmunicipality where the project is situated. The procedure is quite the same as under category 1 (above)
Build SHP plant
Costing of the procedures
In Flanders, a contract is needed with the local distribution operator (DNB) in order to connect the production site to the grid. The cost of the connection depends on the voltage level, the connection cost and the type of connection, tariffs are available on the site www.creg.be.

1.2.2. Wallonia

There are several key steps to follow when organising and applying for all relevant permits required for the development of SHP plants in Wallonia. The below guidelines cover permits from the first stages of land procurement to the latter ones when connecting the completed plant to the grid network.

The first stage is related to the legal possibility of using the waterway as an energy source. This depends on the potential location of the site. In case of being located on public domain (typically defined as a waterway managed by the public authorities of the Navigable Waterways Department (*Direction Générale Opérationnelle de la Mobilité et des Voies Hydrauliques*, DGO2) the plant would need an authorisation (*autorisation*) delivered by the same administration. If the site is located on the private domain (mainly private owners, typically of old mills) a right to use the energy of the waterway (*droit d'eau*) would be necessary to proceed.

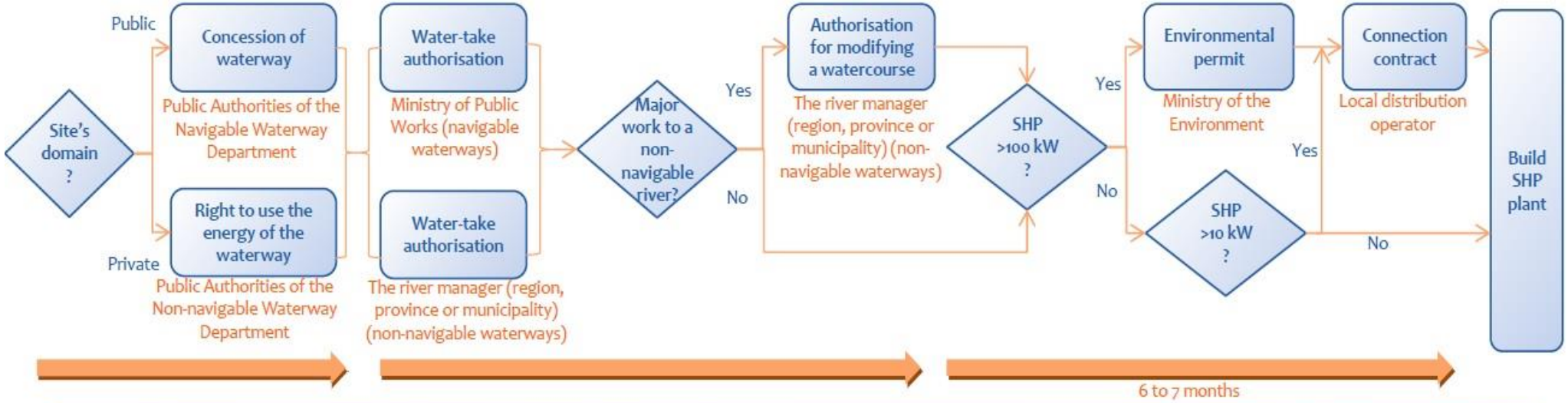
The next permit or permits required are the water take authorisation (*autorisation de prise d'eau*)[1] and/or depending on the importance of changes brought to the non-navigable waterway during the civil work, the authorisation for modifying a watercourse (*autorisation de modification de cours d'eau*) which are delivered by the Ministry of the Environment from the Non-navigable Waterways Department which is free of charge and the time taken to complete is unknown as there is no compulsory time frame within the legislation. The delivered permits will mention the imposed residual water flow (*débit réservé*).

The request of an environmental permit is compulsory for every plant with a potential power output above 100 kW. This permit is reviewed and delivered on a case-by-case basis for each specific project. The permit usually takes between 160 to 190 days to be issued and it is free of charge. However, new legislation is under preparation and currently being revised. Most probably, all plants, including those from 0 to 100 kW, will need to apply for an environmental permit in the future.

Lastly, for projects with a power output above 10 kW, a connection contract is needed to enable the injection of the electricity to the grid. The contract is set with the local distribution operator (*gestionnaire de réseau de distribution*) or different actors depending on the location of the project (http://www.cwape.be/). The length of the procedures depends on the installed capacity and the voltage (low or high) of the plant as described in the technical legislation (*règlements techniques distribution et transport local*). The cost of the connection depends on the voltage level, the connection post and the type of connection. Tariffs are available on http://www.cwape.be/.

[1] Delivered: if the waterway is navigable, by the Territorial Direction of the Navigable Waterways (*Direction Territoriale des Voies Hydrauliques*) in name of the ministry in charge. If the waterway is non-navigable, by the manager of the waterway (depending on the importance of the waterway: the local authority -commune-, the province or the Walloon region).

Belgian Permit process for SHP (Wallonia)



Costing of the procedures

- Costs are very difficult to calculate because of the varying natures of the projects.
- The authorizing development and use of water permits are both free of charge.
- The last two stages vary on a case-by-case basis and therefore, particularly the connection contracts which cost a variable amount being dependent on the amount of installed capacity.
- Potential changes to the legislation: The environmental permit, as shown, is presently needed for only SHP plants above 100 kW in power output. However, amendments to this legislation are under discussion. The new legislation may require a permit for plants with an installed capacity below 100 kW.

1.3. Obtaining Permits for Small Hydropower Plants in France

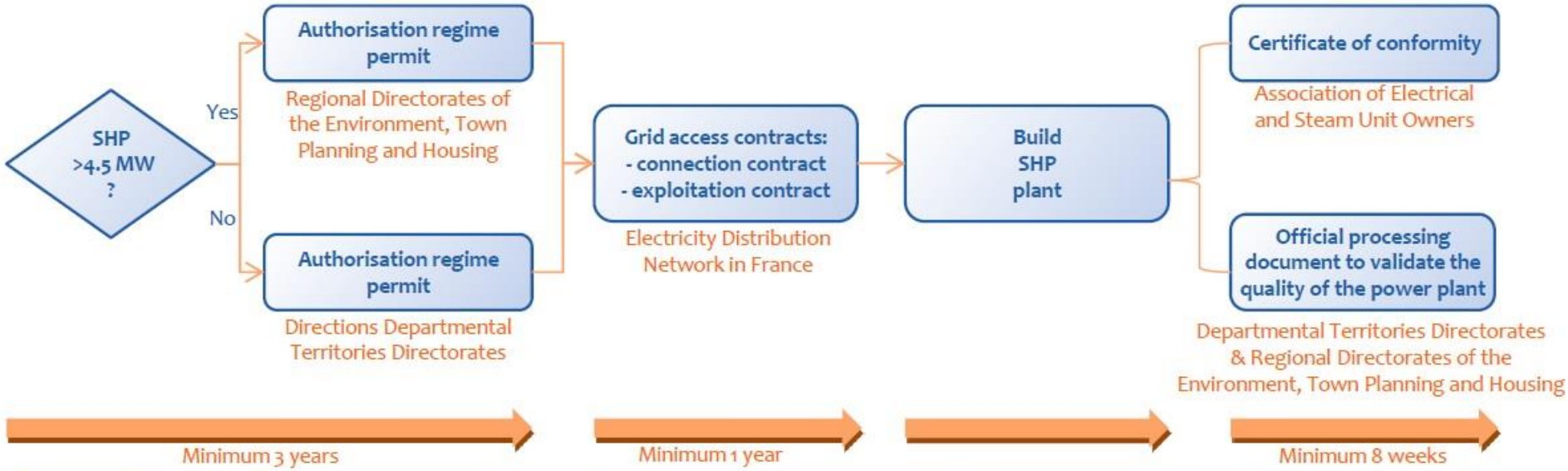
There are few necessary guidelines to follow when organising the development SHP plants in France. The guidelines below bring help from the first stages of authorising the development until the validation from the local authorities before starting to operate the plant. Total costs vary case-by-case (around 3,500 EUR/kW to 5,000 EUR/kW) and are also rising due to environmental constraints.

The first stage is the receipt of the planning permission and the overall authorisation to build and renew the use of an existing plant. The application procedure, in the case of hydropower plants under 4.5 MW, is organised and authorised by the Directions Departmental Territories Directorates (*Départementales des Territoires*, DDT) and takes up to a minimum of three years (three to ten years roughly). Also, costs can vary due to the differing sizes of the developments and depend on the amount of engineering works needed. Furthermore such costs are rising due to environmental constraints. If the power plant is over 4.5 MW, an authorisation from the Ministry of the Environment (*Directions Régionales de l'Environnement, de l'Aménagement et du Lodgement*, DREAL) is required. This permit takes as well a minimum of three years.

The next crucial stage surrounds the practicality of gaining access to the electricity network. A grid access contract (*Contrat d'Accès au Réseau de Distribution*, CARD I) is required and available from the Electricity Distribution Network in France (*Électricité Réseau Distribution France*, ERDF). This usually takes approximately one year and costs between 200 EUR/kW and 500 EUR/kW or more, depending on the distance to cover and the power capacity of the transformer station.

Lastly, other validations are needed. The first being a certificate of conformity (*consuel, attestation de conformité de l'installation*) which can be applied for at the Association of Electrical and Steam Unit Owners (*Association des Propriétaires d'Unité Électrique et de Vapeur*, APAVE). The second is an official processing document to validate the quality of the power plant (*procès-verbal de récolement*) from DREAL. This takes a few weeks.

French Permit process for SHP


SHP >4.5 MW ?
Yes
No
Authorisation regime permit
Regional Directorates of the Environment, Town Planning and Housing
Authorisation regime permit
Directions Departmental Territories Directorates
Grid access contracts:
- connection contract
- exploitation contract
Electricity Distribution Network in France
Build SHP plant
Certificate of conformity
Association of Electrical and Steam Unit Owners
Official processing document to validate the quality of the power plant
Departmental Territories Directorates & Regional Directorates of the Environment, Town Planning and Housing
Minimum 3 years
Minimum 1 year
Minimum 8 weeks

Costing of the procedures

- Concerning the monetary costs involved for all stages of the process, there cannot be a single figure provided. Almost all of the aforementioned stages need studies that have to be drafted in the free market, where prices are highly competitive.
- Costs for the planning and building permissions vary greatly due to the differing sizes of the developments thus affecting the amount of engineering works necessary.
- For the environmental permits again costs would be calculated case by case dependant on the amount of power output.
- The grid connection contracts generally cost a minor amount between 200 EUR and 500 EUR.
- Total costs are estimated to be around 3,500 EUR/kW to 5,000 EUR/kW.

1.4. Obtaining Permits for Small Hydropower Plants in Greece

There are many necessary guidelines to follow when developing SHP plant in Greece. The below detailed procedures highlight the permits needed for all steps of the process including physical planning licenses, environmental obligations, network connection and infrastructure installation authorisations and finally the potential operation licenses of the plants.

The first stage should be the application for the initial production license (*άδεια παραγωγής*) to the Regulatory Authority for Energy (RAE) (*Ρυθμιστική Αρχή Ενέργειαςmm*, PAE) which is required for all potential power plants with an intended output of more than 50 kW. For plants that would have a power output of less than 50 kW there is no need for a production license. This application procedure will take around six months.

The following authorisations should be applied for at the same time. These are firstly the approval of environmental terms (EPO) (*Έγκριση Περιβαλλοντικών Όρων*, ΕΠΟ), either to the central division in the Ministry of the Environment (*Ειδική Υπηρεσία Περιβάλλοντος*, ΕΥΠΕ) or to the decentralised local authorities (*αποκεντρωμένη διοίκηση*), which should take about two years. Additionally, as part of this process the Local Forest Department (*Δασαρχείο*) will examine the EPO, to preliminary approve the power plant proposals which take around three months to be complete. After this, an application should be made to the electricity transmission operators PPC/ADMIE or DEDDIE for a non-bound grid offer (*μη δεσμευτική προσφορά όρων σχύνδεσης*), which should take about a year.

After receiving an approval of the EPO, an application to the decentralised local authorities for a water usage license is needed. This should take around nine months. Additionally, it is necessary to ask the electricity transmission operators if the non-bound grid offer has been approved and can now become a bound grid offer (*δεσμευτική προσφορά όρων σχύνδεσης*). In total, this should similarly take around six months. Once both have been completed, an application for the installation license (*άδεια εγκατάστασης*) should be submitted to the Ministry of the Environment (RES division) (*Υπουργείο Περιβάλλοντος, Ενέργειας και Κλιματικής Αλλαγής*, ΥΠΕΚΑ) or to the decentralised local authorities, which can take up to a further three months.

At this stage, ideally, an application to the Local Forest Department should be made which would result in the receipt of an approval of intervention (*έγκριση επέμβασης*). The waiting time to receive this can also take up to a period of six months. At this stage you should be ready to sign a connection treaty (*σχύμβαση έργων σχύνδεσης*) with the relevant electricity transmission operator. This can take up to a further three months.

Now with all these successfully applied for, received and in place it is time to build the SHP plant where the following must be undertaken in this order to be approved. First,

there is a need to apply to the Local Forest Department for the permission to start a business in the area (*πρωτόκολλο εγκατάστασης*). Secondly, it is necessary to sign a buy & sell electrical power treaty (*σςύμβαση αγοραπωλησίας ηλεκτρικής ενέργειας*) to/from PPC/LAGIE. Both actions should take about six months. After completion of the previous steps, construction works for the grid infrastructure in order to connect to the public electricity grid and the rest of the plant infrastructure can start. This can take up to around two years.

The plant should now be tested in a suitable environment for a further three months. Finally, it is necessary to apply for the operation license (*άδεια λειτουργίας*) to the Ministry of the Environment (RES division).

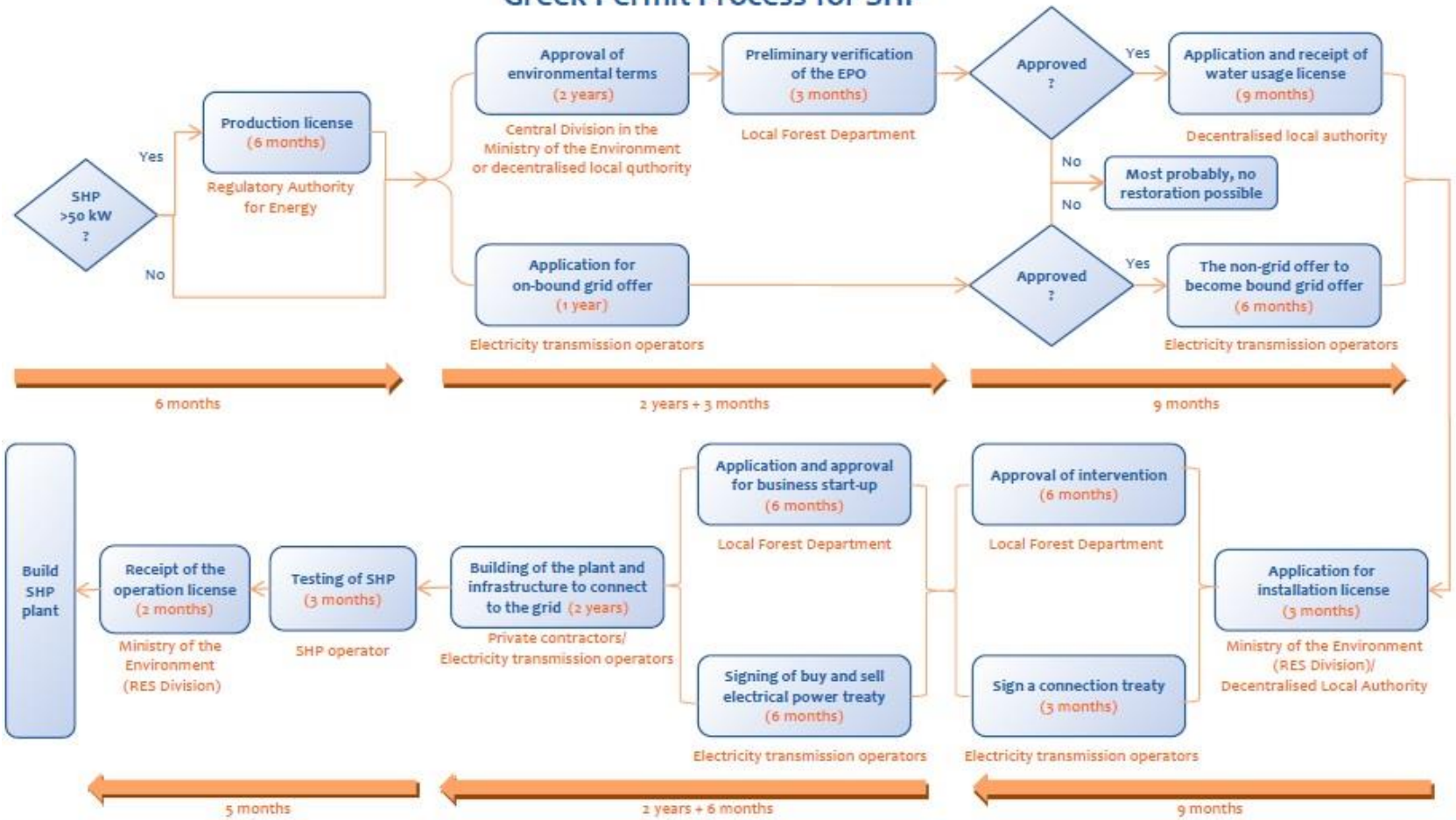
When all the above steps have been completed, the power plant will be ready for operation. In total, the whole regulatory/construction period is expected to last about seven years.

Concerning the monetary costs (*χρηματικό κόστος*) involved for all stages of the process, a single figure cannot be provided. Almost all of the aforementioned stages need studies that have to be drafted in the free market, where prices are highly competitive. Minor costs are paid every year to the authorities that participate in the licensing procedure.

It is very important that the costs of the company for the seven years of the licensing procedure are being considered. However, these costs depend on the type of company selected (S.A., Ltd. O.E., E.E., etc.) which may vary considerably each year.

As a conclusion, it is very difficult to make any official (i.e. binding) estimation for the costs that are related to the licensing procedure for a SHP plant. However a very loose estimation of the potential costs is described. Costs related to the development of a SHP range between 50,000 EUR/plant to 100,000 EUR/plant (please note: not per MW). The costs related to the company itself range between 40,000 EUR/company to 80,000 EUR/company (please note: not per MW), assuming that each company will operate two plants. From the above, it comes that the development, licencing and company costs altogether range between 70,000 EUR/plant to 140,000 EUR/plant, for 2013.

Greek Permit Process for SHP


SHP >50 kW ?
Yes
No
Production license (6 months)
Regulatory Authority for Energy
Approval of environmental terms (2 years)
Central Division in the Ministry of the Environment or decentralised local quthority
Preliminary verification of the EPO (3 months)
Local Forest Department
Approved ?
Yes
No
Application and receipt of water usage license (9 months)
Decentralised local authority
Most probably, no restoration possible
Application for on-bound grid offer (1 year)
Electricity transmission operators
Approved ?
Yes
No
The non-grid offer to become bound grid offer (6 months)
Electricity transmission operators
6 months
2 years + 3 months
9 months
Application and approval for business start-up (6 months)
Local Forest Department
Approval of intervention (6 months)
Local Forest Department
Application for installation license (3 months)
Ministry of the Environment (RES Division)/ Decentralised Local Authority
Building of the plant and infrastructure to connect to the grid (2 years)
Private contractors/ Electricity transmission operators
Signing of buy and sell electrical power treaty (6 months)
Electricity transmission operators
Sign a connection treaty (3 months)
Electricity transmission operators
Testing of SHP (3 months)
SHP operator
Receipt of the operation license (2 months)
Ministry of the Environment (RES Division)
Build SHP plant
5 months
2 years + 6 months
9 months

Costing of the procedures

- Concerning the monetary costs involved for all stages of the process, there cannot be a single figure provided. Almost all of the aforementioned stages need studies that have to be drafted in the free market, where prices are highly competitive. Minor costs that are not worth mentioned are paid every year to the authorities that participate in the licensing procedure.
- It is very important to consider the costs of the company for the 7 years of the licensing procedure. However, these costs depend on the type of company selected (S.A., Ltd. O.E., E.E., etc.) which may vary considerably for each year.
- Costs related to the development of a SHP range between 50,000 EUR/per plant and 100,000 EUR/per plant.
- Costs related to the company range between 40,000 EUR/per company and 80,000 EUR/per company (under the assumption that each company will operate 2 plants).
- Development, licencing and company costs range between 70,000 EUR/per plant and 140,000 EUR/per plant.

1.5. Obtaining Permits for Small Hydropower Plants in Italy

There are several stages to adhere to when applying for all relevant permits required for developing SHP plants in Italy.

The instructions below cover all the main aspects since there is a national legislative framework both for water and renewable energy (RE) regulation. However, some steps can vary from region to region. Many regions approve their own administrative rules and adapt the general procedure to their particular situation.

The general procedure includes:

a) A water concession, normally released by the Water Department. However, each region has different procedures and in some cases the same department can be in charge for both water and energy issues. The time requested goes around one to three years. It would be one year in the case of very small concessions or for the renewal of expiring ones.

b) A single permit (*autorizzazione unica*) introduced by the Legislative Decree n. 387/2003. This is an all-inclusive authorisation to set up and run a plant for all RE developers, issued by the Energy Department. The single permit procedure includes all the necessary permits that are not already included in the concession for the water use, like the authorisation for new grid infrastructures. The time requested goes around one to two years.

c) The *Procedura Autorizzativa Semplificata* (PAS), alternative to the single permit and only for owners of very small plants (up to 100 kW or more, depending on the regional legislation) whose existing structures are already connected to the grid (i.e. in case of old mills refurbishment). In this case is sufficient for them sending an application which includes all the project details to the local authority (municipalities) 30 days before starting with the construction. In the case of experiencing any problems with the application or the project itself, the municipality has competency for stopping the works and ask for clarifications. Otherwise, if after 30 days no feedback has been given from the municipality, the project can be considered as approved and the PAS is valid for three years.

d) An Environmental Impact Assessment (EIA) if requested. This process, if needed (i.e. for plants up to 10 MW; and, after a screening procedure, eventually for plants up to 200 l/sec or 100 KW of installed power) should be included within the concession procedure. This is carried out with the Environmental Department. The time requested for the EIA ranges between six months and two years

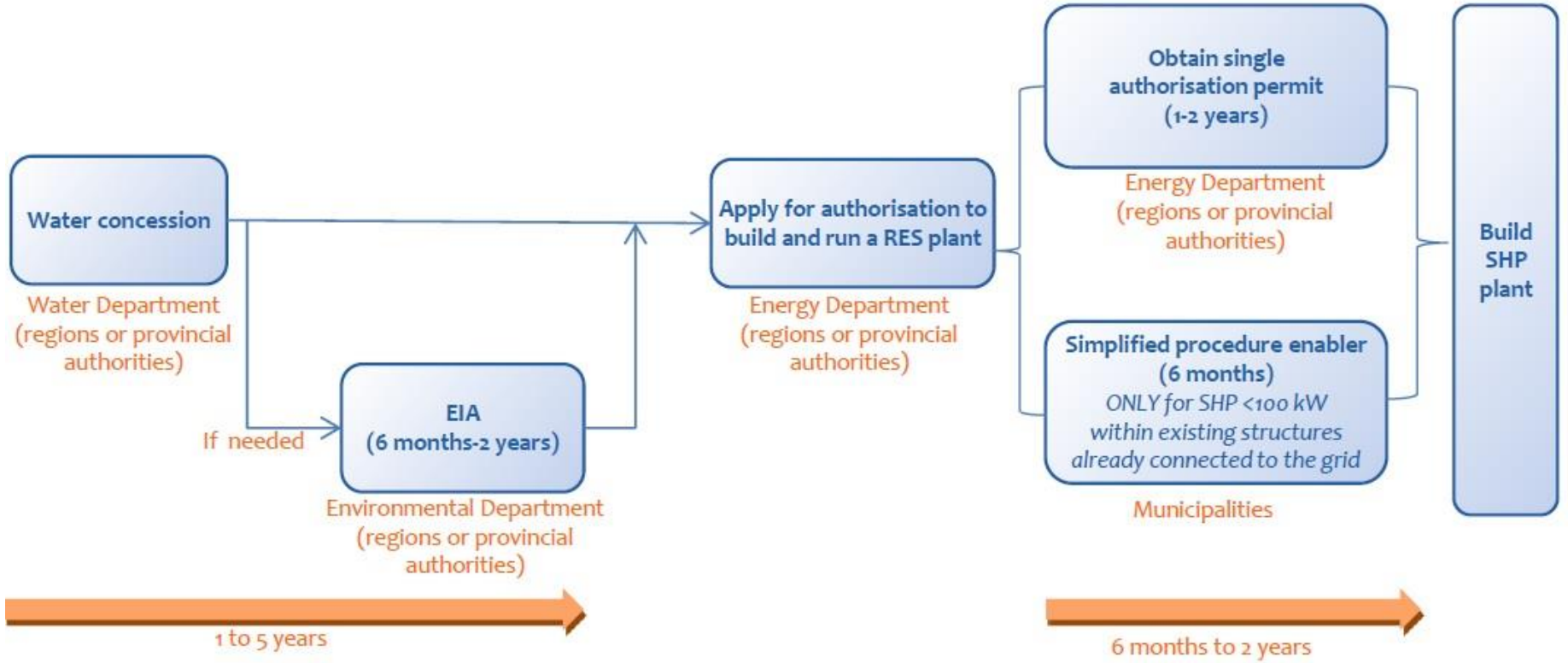
A simple guide on the overall authorisation process and on the regional procedures can be found on the website of the Energy System Manager (*Gestore dei Servizi Energetici*):

http://www.gse.it/it/EnergiaFacile/Autorizzazioni/Pagine/default.aspx.

Usually, the overall procedure for new hydropower plants lasts around one to four years, depending on the plant size and legal requirements. The Legislative Decree n. 28/2011 established that the single permit procedure should take no more than 90 days, but this time limit does not include the specific terms for the EIA procedure (by law 90-150 days) and for the concession.

The cost of the whole process can vary significantly, depending mainly on the plant size and on the need to make an EIA (from 10% of the overall investment cost, in case of very simple procedure, up to 15% of the investment cost when the EIA is requested). For small and low head plants the investment cost is usually around 4,500 EUR/kW. This means that the cost for the authorisation starts from around 5,000 EUR and can reach up to 65,000 EUR.

Italian Permit Process for SHP


Water concession
Water Department (regions or provincial authorities)
If needed
EIA (6 months-2 years)
Environmental Department (regions or provincial authorities)
1 to 5 years
Apply for authorisation to build and run a RES plant
Energy Department (regions or provincial authorities)
Obtain single authorisation permit (1-2 years)
Energy Department (regions or provincial authorities)
Simplified procedure enabler (6 months)
ONLY for SHP <100 kW within existing structures already connected to the grid
Municipalities
6 months to 2 years
Build SHP plant

Costing of the procedures

The cost of the whole process can vary significantly, depending mainly on the plant size and on the need to make an EIA, from a 10% of the overall investment cost in case of very simple procedure up to 15% of the investment cost when the EIA is requested. For small and low head plants the investment cost is usually around 4,500 EUR/kW, and this means that the cost for the authorisation starts from around 5,000 EUR and can reach 65,000 EUR.

1.6. Obtaining Permits for Small Hydropower Plants in Lithuania

There are several key guidelines to follow when applying for all relevant permits required for organising and developing SHP plants in Lithuania. The instructions below cover all phases of the development process from the initial land and property procurement to the power purchasing agreements when connecting to the electricity grid. The authorisation procedure depends on what is needed for the specific potential sites and it can take between six months and two years to be completed.

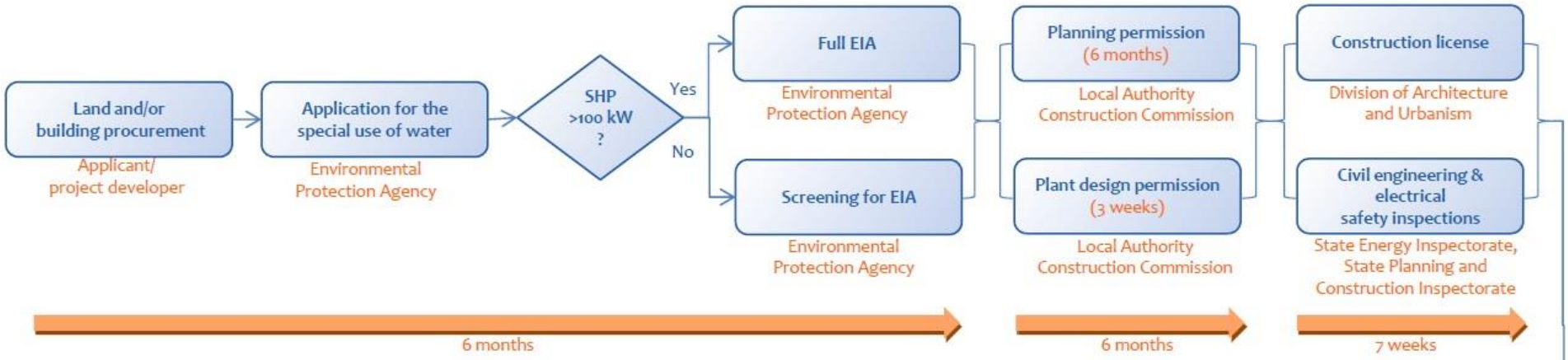
After the initial stages of the land and building procurement it is necessary to gain a permit for the special use of water from the Environmental Protection Agency (*Aplinkos Apsaugos Agentura*) which may take up a few weeks and is free of charge. This includes also the EIA. It can be either a mandatory requirement or screening (depending on scheme size, impounding reservoir volume). However SHP plants with power capacities below 100 kW are exempt from the EIA. The screening for the EIA is not costly while the full EIA can reach tens of thousands of euros and more which is all dependent on the specific characteristics of each site.

The following step is to apply for a planning permission procedure from the Construction Commission of the local municipality (*Savivaldybe Statybu Komisija*). The process from the application to its approval can take between one week and several months. The costs are variable and they can reach up to a thousand of euros. Furthermore, it is necessary to have a planning consent for the SHP plant design which can also take usually up to a few weeks and is free of charge.

In addition to the planning consents, gaining a license for construction is traditionally needed from the Division of Architecture and Urbanism of the local borough (*Savialdybes Architekturos ir Urbanistikos Skyrius*) and may take up to an extra one and a half months. After this step, civil engineering and electrical safety inspections from State Energy Inspectorate (*Valstybine Energetikos Inspekcija*) more specifically the State Territorial Planning and Construction Inspectorate (*Valstybine Teritoriju Planavimo ir Statybos Inspekcija*) are required before the commissioning of the plant. This can take up to one week and it costs a negligible amount. After this, a State Commission is formed for the commissioning of the plant. A recently introduced online system (INFOSTATYBA) contains all the documents necessary for licensing SHP constructions and facilitates greatly the above procedures.

Finally, it is necessary to gain a license for power generation called the power generated from RES purchase agreement (*elektros energijos supirkimo is atsinaujinanciu energijos isteklių gamintojo sutartis*) which is gained from the LESTO local area (LESTO *teritorinio skyriaus*) and a power purchase agreement from power companies (AB LESTO) which can take up to a further few weeks and both are also free of charge.

Lithuanian Permit Process for SHP



Costing of the procedures

- The application and processing of the application for the special use of water is free of charge. The adjoining EIA has a price which ranges from low for the screening EIA to tens of thousands of euros for the full EIA.
- The costs of processing planning applications charged by the Construction Commission in the relevant authority can vary from a negligible amount up to a thousand euros.
- The construction and design licenses including the civil engineering and electrical safety inspections from mentioned are all of negligible amounts compared to other costs.
- For licenses of power generation such as the power generated from renewable energy sources and the power purchasing agreements come all free of charge.

1.7. Obtaining Permits for Small Hydropower Plants in Poland

There are several steps which need to be considered when applying for permits required for SHP plants in Poland. The below instructions cover the main facets of the permit procedure and it is considered that the authorisation process for developing sites for SHP would take approximately between one and four years. Due to the fact that costs often depend on the capacity of an SHP, they are estimated for a 100 kW SHP plant.

First, the environmental impact of the development needs to be considered therefore it takes approximately between four and twelve months for the office of the mayor at the local administration (*wójt gminy* or *burmistrz/prezydent miasta*) to make the environmental decision (*ecyzja o środowiskowych uwarunkowaniach realizacji przedsięwzięcia*) which must be previously approved by the Regional Directorate for Environmental Protection (*Regionalna Dyrekcja Ochrony Środowiska*, *RDOŚ*). The cost will differ depending on the necessity of preparing the report on the environmental impact. In most cases the information card of an enterprise provided by the developer will not be considered as sufficient and an environmental impact assessment report will be required. The cost of the report could be at least 40,000 PLN (9,500 EUR).

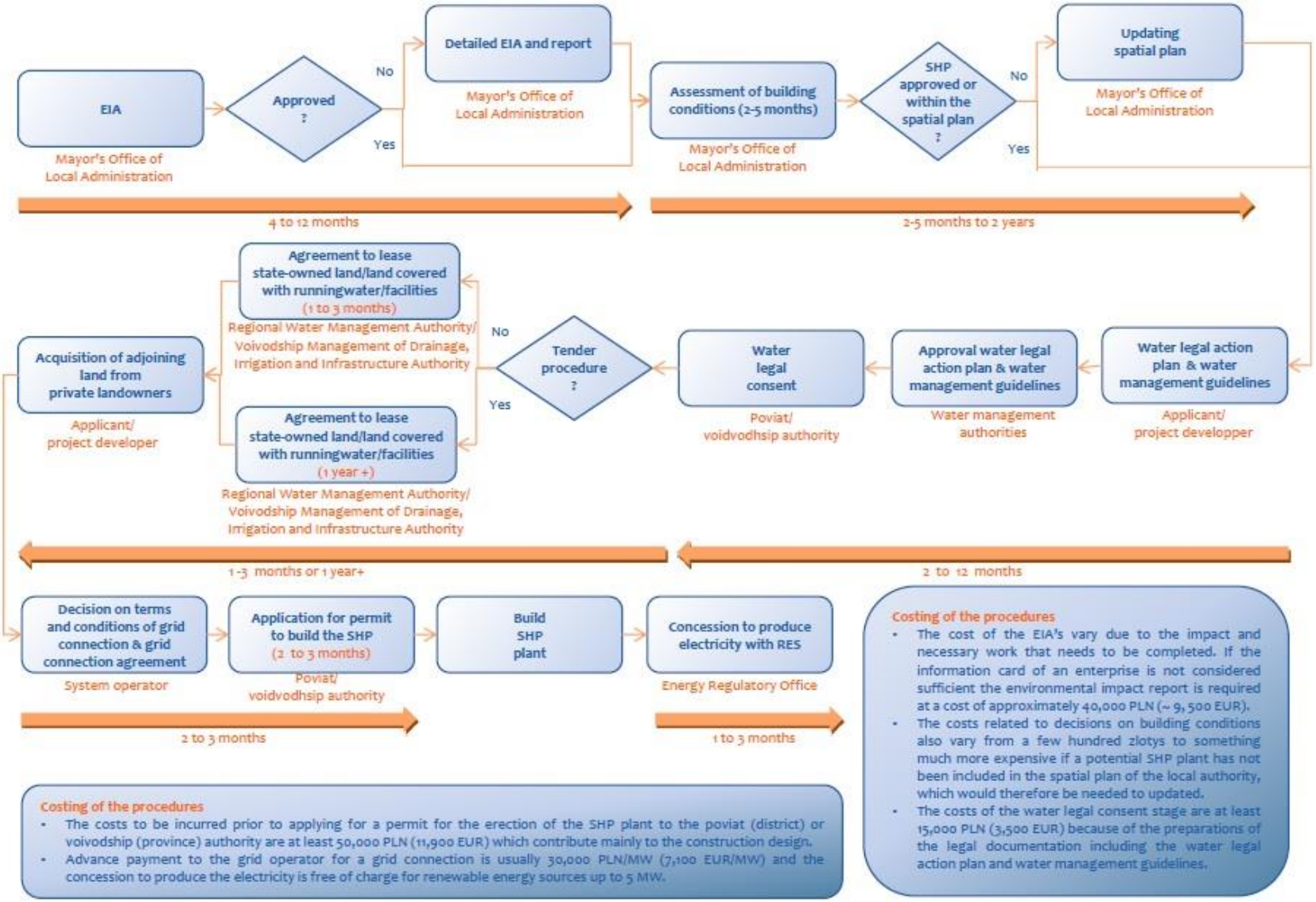
Furthermore, the decision on building conditions (*warunki zabudowy*) is necessary and issued by the local administration (*wójt gminy* or *burmistrz/prezydent miasta*); unless, in rare cases, there is a spatial development plan covering the investment area. Obtaining the decision on building conditions may take between two and five months and the costs related to this stage will be a hundred zlotys (mostly the costs of relevant maps). In case there is a spatial development plan and a SHP plant is not included within, the procedure of changing the plan would take around two years and may be more expensive. A water-legal consent (*pozwolenie wodoprawne*) needs to be gained from the poviat or voivodship authority (*starosta* or *marszałek województwa*) which can take between two months to one year. The main costs involved here will be at least around 15,000 PLN (3,500 EUR) for the water-legal action plan (*operat wodno-prawny*) and water management guidelines (*instrukcja gospodarowania wodą*).

The next important stage is to acquire the rights to manage the real estate property of the State Treasury (i.e. lands covered with running water and most probably the weir) from one of the institutions which are responsible for the maintenance and ownership supervision over the estate. This will be the Regional Water Management Authority (*Regionalny Zarząd Gospodarki Wodnej, RZGW*) or Voivodship Management of Drainage, Irrigation and Infrastructure Authority (*Wojewódzki Zarząd Melioracji i Urządzeń Wodnych, ZMiUW*) depending on the river. In case the developer needs to lease the weir it may take around a year or more for a tender to be announced by the property manager. In case where no tender is necessary it will take between one and three months to obtain the agreement to lease lands or facilities. It is worth mentioning that

the executory regulations pertaining to allow investors utilisation of state-owned weirs are missing in Poland and legal decisions in this respect depend on local conditions. The leasing instalments will depend on the area of the land and the planned energy generation of the SHP or the offer given in the tender. An acquisition of lands adjoining the river form private owners will also be needed at this stage; however, it is recommended to ensure the rights to privately owned lands (necessary for the investment) at the very beginning of the investment process.

The finishing juncture of the procedure is to acquire a permit for erection (*pozwolenie na budowę*) through an application to poviat or voivodship authority (*starosta* or *wojewoda*) which takes only two to three months costing at least 50,000 PLN (11,900 EUR); mainly for the cost of the construction design. Apart from the decisions above, to start operating a power plant a decision on terms and conditions of grid connection (*warunki przyłączenia do sieci*) and subsequently a grid connection agreement (*umowa przyłączeniowa*) is required from the system operator (*Operator Systemu Dystrybucyjnego*). The advance payment for a grid connection costs 30,000 PLN/MW (7,100 EUR/MW). Finally the concession to produce the electric energy from RES (*koncesja na wytwarzanie energii elektrycznej w OZE*) will be needed from the Energy Regulatory Office (*Urząd Regulacji Energetyki*). Gaining it is free of charge for RES with installed capacity up to 5 MW.

Polish Permit Process for SHP


EIA
Mayor's Office of Local Administration
Approved ?
No
Yes
Detailed EIA and report
Mayor's Office of Local Administration
4 to 12 months
Assessment of building conditions (2-5 months)
Mayor's Office of Local Administration
SHP approved or within the spatial plan ?
No
Yes
Updating spatial plan
Mayor's Office of Local Administration
2-5 months to 2 years
Water legal action plan & water management guidelines
Applicant/ project developper
Approval water legal action plan & water management guidelines
Water management authorities
Water legal consent
Poviat/ voidvodhsip authority
Tender procedure ?
No
Yes
Agreement to lease state-owned land/land covered with runningwater/facilities (1 to 3 months)
Regional Water Management Authority/ Voivodship Management of Drainage, Irrigation and Infrastructure Authority
Agreement to lease state-owned land/land covered with runningwater/facilities (1 year +)
Regional Water Management Authority/ Voivodship Management of Drainage, Irrigation and Infrastructure Authority
Acquisition of adjoining land from private landowners
Applicant/ project developer
1 -3 months or 1 year+
2 to 12 months
Decision on terms and conditions of grid connection & grid connection agreement
System operator
Application for permit to build the SHP (2 to 3 months)
Poviat/ voidvodhsip authority
Build SHP plant
Concession to produce electricity with RES
Energy Regulatory Office
2 to 3 months
1 to 3 months
Costing of the procedures
The cost to be incurred prior to applying for a permit for the erection of the SHP plant to the poviat (district) or voivodship (province) authority are at least 50,000 PLN (11,900 EUR) which contribute mainly to the construction design.
Advance payment to the grid operator for a grid connection is usually 30,000 PLN/MW (7,100 EUR/MW) and the concession to produce the electricity is free of charge for renewable energy sources up to 5 MW.
Costing of the procedures
The cost of the EIA's vary due to the impact and necessary work that needs to be completed. If the information card of an enterprise is not considered sufficient the environmental impact report is required at a cost of approximately 40,000 PLN (~ 9, 500 EUR).
The costs related to decisions on building conditions also vary from a few hundred zlotys to something much more expensive if a potential SHP plant has not been included in the spatial plan of the local authority, which would therefore be needed to updated.
The costs of the water legal consent stage are at least 15,000 PLN (3,500 EUR) because of the preparations of the legal documentation including the water legal action plan and water management guidelines.

1.8. Obtaining Permits for Small Hydropower Plants in Slovenia

These guidelines cover all the important stages in the investment process to develop a SHP plant in Slovenia. The stages are covering the steps of the preliminary, planning, construction, and electricity production phase.

The first or preliminary phase serves the investor to check the feasibility of the idea to construct the SHP plant. If the technical, administrative, legal and financial results show positive, the investor can proceed to the next phase. The following steps must be considered:

a. Analysis of the potential suitability of the location should be undertaken by an expert. This step can take up to two months to complete.

b. During the preliminary planning phase the investor acquires the planning information (*lokacijska informacija*). It is issued by the municipality. The costs are around 20 EUR.

c. Following the rough selection of the location more precise data needs to be gathered, like hydrological data, geology information etc. which forms a base of the conceptual and preliminary design and feasibility studies. Those are prepared by an expert company, and can take up to one year to complete.

d. The costs for this phase vary according to various conditions (location access, hydrology measuring period, other factors), but should not exceed 0.5% of the total investment costs (TIC). The whole process can last up to one year.

The second phase is intended to obtain the necessary permits and agreements which are required for the water permit application, as well as to obtain the water permit itself (or water right in general). The water permit is needed for hydropower plants with an installed power below 10 MW. The following steps must be considered:

a. Preliminary specific permissions have to be acquired for obtaining the water right:

- Consent by Fishery Organisation (*Ribiška Družina in Ribiška Zveza Slovenije*).
- Consent by Institute of the Republic of Slovenia for Nature Conservation (*Zavod RS za Varstvo Narave*).
- Proof of land access or ownership for all the land where objects of SHP are located.
- Water permit (*vodno dovoljenje*) issued by the Environmental Agency (*Agencija RS za okolje*). The official time for response is three months. The cost is 22.66 EUR.
- Water consent (*vodno soglasje*) issued by the Environmental Agency.
- EIA (*Presoja Vplivov na Okolje*), required by the Environmental Protection Law for a SHP plant with an installed power equal or larger than 1 MW. Produced by an expert company. Production time is up to three months. Its cost is around 2,000 EUR.

- Environmental consent (*okoljevarstveno soglasje*) issued by the Ministry of Agriculture and the Environment (*Ministrstvo za Kmetijstvo in Okolje*) for SHP plants which are required to obtain the EIA. The issuing time is up to three months. The cost is 22.66 EUR.
- Calculation and determination of the reserved flow or minimum flow (ekološko sprejemljivi pretok, QES).
- Energy permit (*energetsko dovoljenje*) needs to be obtained for SHP with installed power above 1 MW. It has to be obtained before deciding the location plan (*lokacijski načrt*). It is issued by the Ministry of Infrastructure and Spatial Planning (*Ministrstvo za Infrastrukturo in Okolje*).

b. The costs for this phase are mainly small taxes (apart from the expert studies like EIA and QES calculation) and should not exceed a couple of hundred euros. The whole process can last up to one year, but the water permit process can last up to ten years.

The third phase includes the acquisition of all technical conditions, consents and permits, required for the construction phase (fourth phase), after the water right plus all the accompanying acts are acquired. The following steps must be considered for the completion of the third phase:

a. Acquiring project design conditions (*pridobitev projektnih pogojev*) and the consent for the grid connection (*soglasje za priključitev na omrežje*). These are requested from all the relevant authorities, like the energy grid operator (*upravljalec energetskega omrežja*), and the local administrative unit (*upravna enota*). The time required is up to three months. Costs are smaller taxes up to 100 EUR.

b. Designing the main project (*projekt za gradbeno dovoljenje*) which is produced by an expert company. The time required is up to one year. Costs are around 2% of the TIC.

c. Obtaining the construction permit (*gradbeno dovoljenje*). It is issued by the local administrative unit. The time required goes up to 45 days. Costs represent 0.01% of TIC plus public utility charges (*komunalni prispevek*). The latter is a substantial cost which is relative to the size of the occupied land and water, electricity and telephone connections (around 30,000 EUR).

d. The consent for the grid design (*soglasje k projektnim rešitvam*) is issued by the grid operator. The time required ranges between 30 and 60 days. There is no cost implied.

e. Signing the contract for the connection to the energy grid (*pogodba o priključitvi na omrežje)*. It is signed with the grid operator. The time required is up to 30 days. There is no cost derived from this activity.

f. The preparation of the tendering documentation for the supply of the equipment and the selection of potential contractors. The documentation is prepared by an expert company and can cost up to 0.1% of TIC (depending on the size and complexity of the SHP

plant). The required time is up to 90 days.

g. The execution design (*Projekt Za Izvedbo del*, PZI) is prepared by an expert company and can cost up to 2% of TIC (depending on the size and complexity of the SHP plant). The time required is up to 120 days.

h. The financial investment program is necessary when the investor needs to apply for the bank loan or other financial sources. It is prepared by the financial expert. The time required is up to 30 days. Costs are up to 3,000 EUR.

The fourth phase comprises the construction of the SHP plant. The following steps must be considered:

a. The construction of the SHP plant (*gradnja MHE*) in all segments (electrical, mechanical, hydro-mechanical, construction) can last up to one and a half years and is performed by the equipment suppliers, construction, and engineering companies. The cost of this part is the biggest of all the investment, reaching around 90% of TIC.

b. Construction of the grid connection and connecting the hydropower plant to the electricity grid of the local grid operator (*priključek na omrežje*). The time required depends on the size of the plant for the construction part and can last up to 10 days for the connection part. The cost is 357.75 EUR. The price is determined by the grid operator (SODO).

This fifth phase encompasses all the works necessary for the technically safe and legally correct operation of the SHP plant. The following steps must be considered for the completion of the fifth phase:

a. The implemented works design (*Projekt Izvedenih Del*, PID) are prepared by an expert company and can cost up to 0.5% of TIC (depending on the size and complexity of the SHP plant). The time required is up to 60 days.

b. The creation of the contract for electricity purchase and sale which is usually proposed by the electricity company (*pogodba o nakupu in prodaji električne energije*). The time required time is usually a few days but it depends on negotiations. There is no cost derived from this activity.

c. The contract for access to the grid (*pogodba o dostopu do omrežja*) is readily available at the grid operator and takes a few days to complete and sign. There is no cost derived from this activity.

d. Upon the review of the realised conditions for the grid connection, a technical inspection (*tehnični pregled*) is requested by the local Administrative Unit (*Upravna Enota*). They organise the inspection inviting all the relevant experts and some inspectors to the SHP site. The time required time ranges between 15 and 60 days. The cost is around 1,500 EUR.

e. After a successful technical inspection the unit is connected to the grid and it becomes ready to begin with its operational life. However, in order to be legally compliant, it is necessary to acquire an operating permit (*uporabno dovoljenje*). The operating permit is crucial permit for the SHP operation. It is issued by the local Administrative Unit. The issuing time is 30 days. The cost is 0.05% of TIC.

The sixth phase is last in the investment process and it includes obtaining the necessary permits to operate within the support scheme for the RES. This enables the operator to sell the produced electricity under the priority grid access and by the price that allows him to secure a 15 years pay-back period. The following steps must be considered for the completion of the last phase:

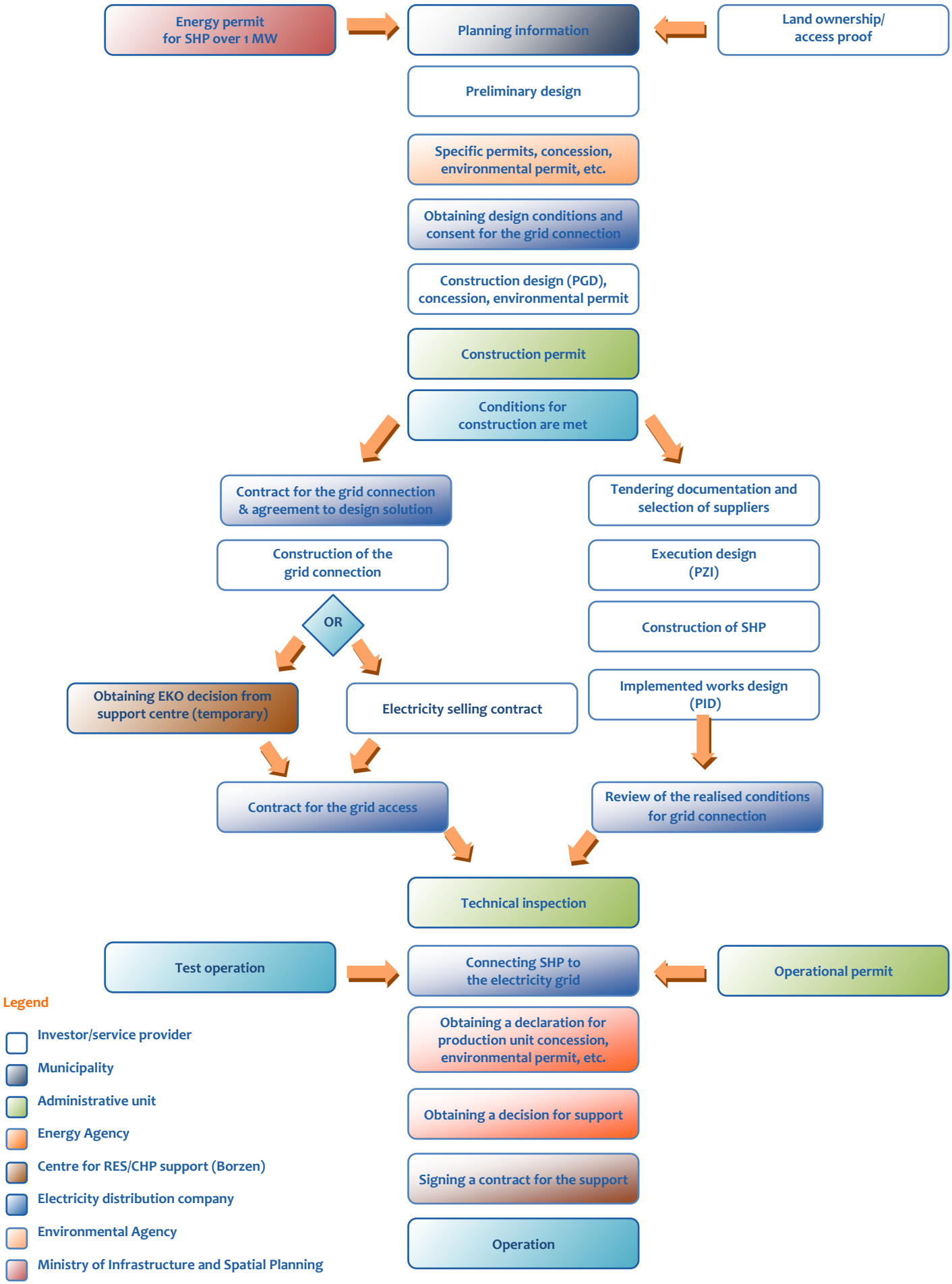
a. Obtaining the declaration for the Production unit (*deklaracija za proizvodne naprave*). It is issued by the Energy Agency (*Agencija RS za Energijo*). The time required is 30 days. There is no cost derived from this activity.

b. Obtaining the decision on the provision of support (*odločba o dodelitvi podpore*). It is issued by the Energy Agency (*Agencija RS za Energijo*). The time required is 30 days. There is no cost derived from this activity.

c. Signing the contract of the provision of support (*pogodba o zagotavljanju podpore*). It is to be signed with the electricity market operator (*Borzen*) and the Support Centre (*Center za Podpore*). The time required is 30 days. There is no cost applied.

d. Another practical measure which needs to be considered is the need to give professional training to people for the operation of the energy facilities. The training is given by the expert company and could take up to three weeks to complete. The cost goes up to 1,500 EUR.

Slovenian Permit Process for SHP


Energy permit for SHP over 1 MW
Planning information
Land ownership/ access proof
Preliminary design
Specific permits, concession, environmental permit, etc.
Obtaining design conditions and consent for the grid connection
Construction design (PGD), concession, environmental permit
Construction permit
Conditions for construction are met
Contract for the grid connection & agreement to design solution
Tendering documentation and selection of suppliers
Construction of the grid connection
Execution design (PZI)
OR
Construction of SHP
Obtaining EKO decision from support centre (temporary)
Electricity selling contract
Implemented works design (PID)
Contract for the grid access
Review of the realised conditions for grid connection
Technical inspection
Test operation
Connecting SHP to the electricity grid
Operational permit
Legend
Investor/service provider
Municipality
Administrative unit
Energy Agency
Centre for RES/CHP support (Borzen)
Electricity distribution company
Environmental Agency
Ministry of Infrastructure and Spatial Planning
Obtaining a declaration for production unit concession, environmental permit, etc.
Obtaining a decision for support
Signing a contract for the support
Operation

1.9. Obtaining Permits for Small Hydropower Plants in Sweden

The following guidelines highlight a model that provides a detailed description of the process to follow when building a SHP plants in Sweden. These guidelines cover a high level of detailed permits, necessary actions, the amount of time and costs of the procedures when implementing SHP schemes. The areas covered include a background to the necessary planning processes, the required permits and legalities and the actual construction of the plant and related infrastructures.

There are three main stages between the plant conception and its final construction. The first stage is the application phase which is to be completed by the project developer or applicant and takes roughly 60 weeks in total. This stage includes a preliminary study, which takes around 15 weeks (*förstudie*); the consultation and decision (*samråd och beslut*), which takes another further 20 weeks; and lastly the full application, including an EIA (*Ansökan inkl.*, MKB), which takes 25 weeks. The preliminary study includes the general planning of the project and verifies any national interests such as Natura2000. This initialises the EIA brought about by the consultation process is a significant part and it brings together all stages of the application. The EIA itself can cost between 10,000 EUR and 25,000 EUR.

The second phase is the handling of the application by the Permitting Authority the Land and Environment Court (LEC) which takes an additional 40 weeks. Additionally, the applicant must pay around 150 EUR to 10,000 EUR to the environmental court to handle the application. In addition, the applicant also must often pay other sorts of investigations required by the court and costs incurred usually vary between 5,000 EUR and 50,000 EUR.

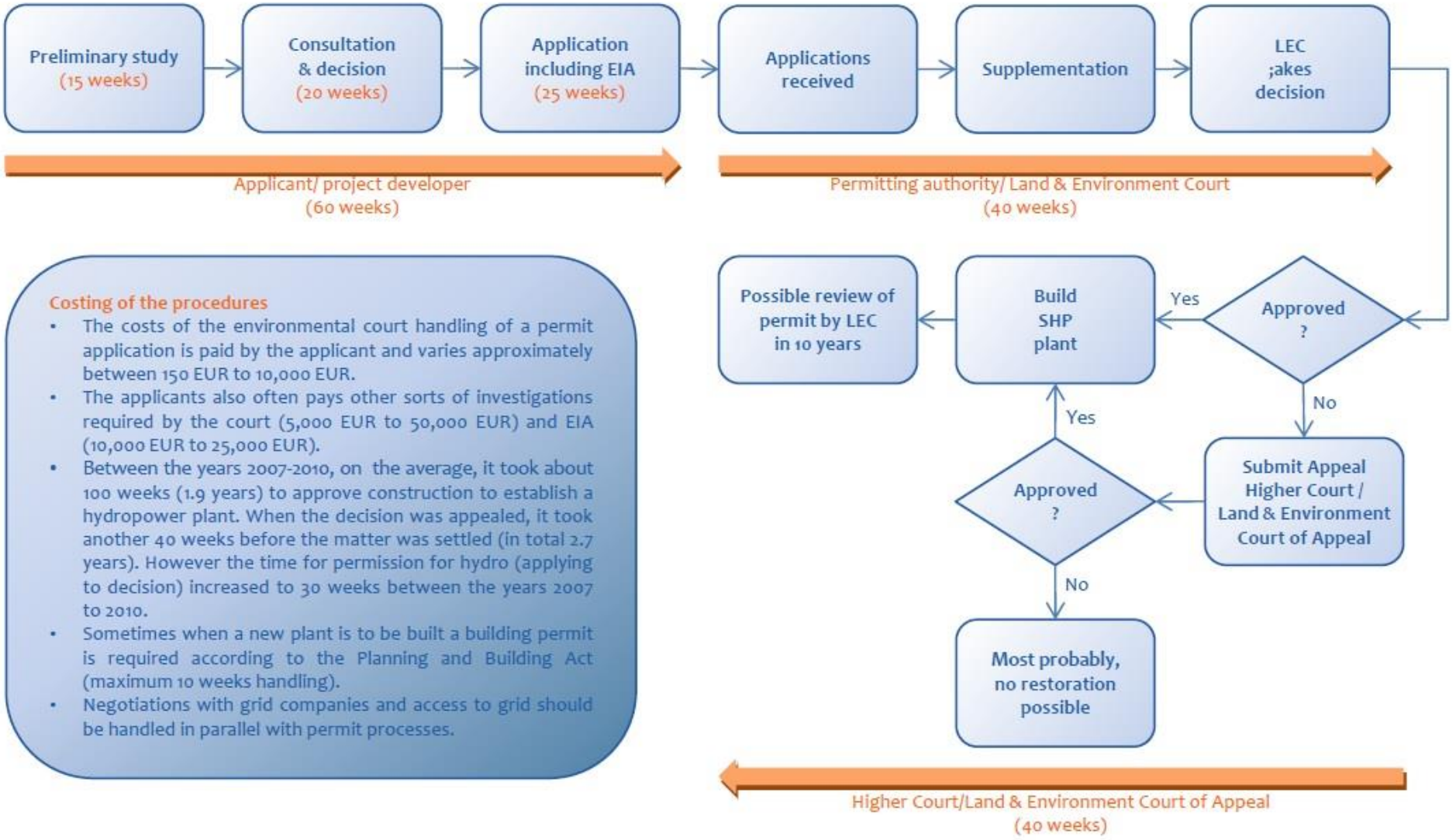
As a first step, the application is received (*ansökan inkommer*) and reviewed with supplementary information (*komplettering*). Afterwards, the LEC makes an announcement and referral (*kungörelse och remiss*) which means a statement is made whether or not more needs to be done before their final decision on the project. Then, after the completion of this, the LEC will make a decision (*beslut*).

The third phase is the final stage and it is completed by the Higher Land and Environment Court of Appeal which takes around 40 weeks. At this stage the plant is either approved or refused. If the decision results in a refusal there is a chance to submit an appeal to the Higher Court. If the plant is approved it is sometimes necessary to gain a building permit which is in accordance with the Planning and Building Act before the construction can be proceeded. This final permit may take up to ten weeks to be processed. While the last stages of the permit are being completed it is necessary to make negotiations with the grid companies in order to guarantee access to the grid as soon as the construction of the plant will be complete, so that the plant will be ready to start producing electricity.

After all phases are complete the SHP plant permits may be subject to review by the LEC after ten years.

It is necessary to bear in mind that these figures for costs and time are based on an average of the years between 2007 and 2010. Between the years 2007 to 2010 it took an average of about 100 weeks (1.9 years) to approve the construction for the establishment of a hydropower plant. If the decision was appealed, it took another 40 weeks before the matter would be settled (in total 2.7 years).

Swedish Permit Process for SHP



Costing of the procedures

- The costs of the environmental court handling of a permit application is paid by the applicant and varies approximately between 150 EUR to 10,000 EUR.
- The applicants also often pays other sorts of investigations required by the court (5,000 EUR to 50,000 EUR) and EIA (10,000 EUR to 25,000 EUR).
- Between the years 2007-2010, on the average, it took about 100 weeks (1.9 years) to approve construction to establish a hydropower plant. When the decision was appealed, it took another 40 weeks before the matter was settled (in total 2.7 years). However the time for permission for hydro (applying to decision) increased to 30 weeks between the years 2007 to 2010.
- Sometimes when a new plant is to be built a building permit is required according to the Planning and Building Act (maximum 10 weeks handling).
- Negotiations with grid companies and access to grid should be handled in parallel with permit processes.

Chapter 2

Technical Plan for Mills Restoration

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2. Technical Plan for Mills Restoration

2.1. Introduction

The restoration of old mills has the basic advantage that most of the potential sites have been already identified while in some cases the civil works are partly completed. The latter strongly depends on the condition of the mill. Critical disadvantage is that the condition of the remaining installation varies significantly from site to site and in some cases heritage issues arise that must be taken into consideration. Concerning the civil works, although it is not always necessary to start from scratch, a certain reduction of the civil engineering works cannot be presumed, since except the current situation, factors such as material used, accessibility, aesthetics etc. affect strongly to the reconstruction cost.

A water wheel is the device that converts the hydraulic energy of running water to mechanical work. Initially, the needs for mechanical energy were limited to the grinding of grains or olives (Roman period) and later for grinding of wood, known as paper mills and as sawmills. As the power required for moving a grain mill is of the order of 3 kW (McGuigan, 1978), these primitive and traditional mills were machines of low performance. This depended on the technical means and the know-how level of the time of construction, the need for power and the mechanical requirements for their fabrication, operation and maintenance. According to Elio Lo Cascio and Paolo Malamina (2006), from late medieval to early modern documentary sources, we know that seldom an ordinary water mill exceeded the power of 3 hp (2.24 kW). Often, the power was lower (around 2 hp) or even less. It must be noticed that, with typical millstones, 1 hp of power to 0.15 quintals of grain per hour were needed (1 quintal corresponds to 100 lb or 48 to 58.7 kg, depending on the local units used at that period). Therefore the mills with water wheels of 2 to 3 hp were able to process 3.5 to 5 quintals (160 to 250 kg) of cereal into flour in 12 hours.

In the early period of the industrial revolution, powerful mills were built to drive transmission shaft for factories, water supply pumps and generators for electricity production. Water mills of this latest period, due to the notable increase of the fabrication possibilities, achieved increased performances with an output power ranging from 3 to 75 kW (University of Southampton, Water wheels). A typical paper mill built in 1892 was driven by a water wheel with output power of 26 to 33 kW.

After the development of steam engines, the needs of industry for energy were covered by the steam engines, while the water wheels continued to serve only regional energy needs. The water wheels of overshot type manufactured in 1880 were 1 to 1.5 m in width, generating 6 to 28 hp (4.5 to 20 kW) of shaft power.

2.2. Types of water wheels

As far as the mechanical equipment is concerned, namely the water wheel, the main advantage for the formulation of a general technical plan is that almost all the wheels can be classified in two types according to the orientation of their axis of rotation:

- Horizontal axis water wheels
- Vertical axis water wheels

In the horizontal axis wheels the wheel is vertical to the axis; therefore, it rotates in a vertical plane (Fig. 1). The main characteristic of the horizontal axis wheel is that it rotates mainly under the action of the gravity of the water. The water is fed to the wheel via a flume striking the paddles (or blades) fitted around the perimeter of the wheel. According to the location of the water inlet in relation to the axis of the wheel the horizontal axis wheel are distinguished in three main types: the overshot wheel, the undershot wheel and the breastshot wheel (Fig. 1a, 1b, 1c)

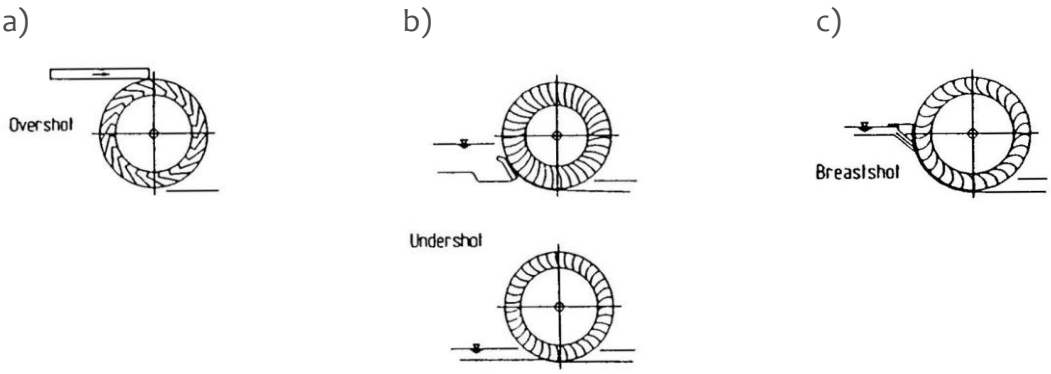


Figure 1a, 1b, 1c: Schematic configuration of water wheels a)Overshot, b)Undershot and c)Breastshot

The operation of vertical axis wheels is based on the conversion of the hydraulic energy of water to mechanical energy. The water in the form of a jet is directed to the buckets of the wheel (runner), and after its impact it changes his momentum and/or height, generating thus a peripheral force and torque to the axis. The operation of this type of wheel is similar to that of action turbines and particularly to the turbine known as Turgo turbine (Fig. 1d).

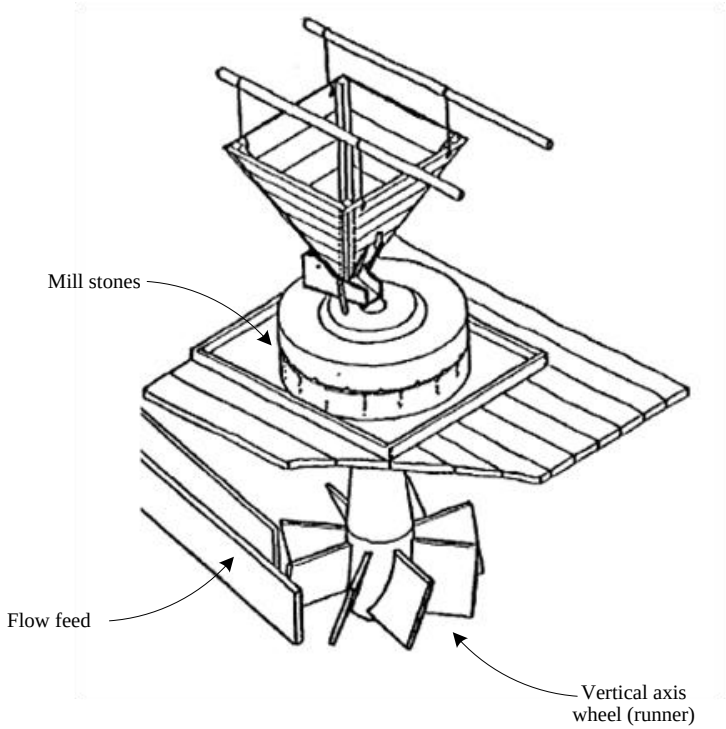


Figure 1d: Schematic configuration of water mill equipped with vertical axis water wheel

After 1850, when the needs of energy and power have grown dramatically, the harnessing of hydraulic energy has been achieved by the modern water wheels, called afterwards as hydraulic turbines. The types of hydraulic turbines used actually are the Francis turbine (developed in 1850), the Pelton turbine (developed in 1880) and the Kaplan or more generally Axial-Flow turbine (developed in 1930). These types of turbines can develop very high amounts of power (up to 600 MW per unit) and therefore the use of the water wheel has been abandoned gradually. In parallel to the large hydraulic power plants, small hydropower (SHP) plants are also developed. A SHP plant is characterised by an installed power less than 10 to 15 MW, depending on the country and the legislation applied. The differences between small and large power plants are located mainly on the application of standardised electromechanical equipment (turbines, generators etc) for the small plants and the way of operation (without the storage of water volume upstream). For the power plants characterised as small (power less than 10 to 15 MW) standardised hydraulic turbines have been developed as Francis, Pelton, S-tube (upstream and downstream), Traflo, Bulb, Cross-Flow, Turgo and some other alternatives. Very recently (about 2005 and afterwards) the Archimedes screw is also used in the reverse operation as water turbine (for power up to 500 kW) to generate electricity from natural flow streams (rivers) or to recover energy from industrial plants.

The water wheels are not anymore fabricated as the needs for harnessing of hydraulic energy from 1 kW up to 600 MW are covered by the hydraulic turbines, of appropriate type and size. The main advantages of hydraulic turbines against the water wheels is the high speed of rotation, the compact size, the high efficiency over a large range of operation, the low cost.

For the case under examination, namely the refurbishment of water mills; two cases are to be taken under consideration:

- The water mill must preserve the traditional view of a water mill but the power produced is transformed to electrical energy as it cannot be absorbed anymore by the millstones. In that case the original water wheel, probably not anymore in operational condition, must be replaced by a similar, specially designed wheel but fabricated by modern materials.
- There is not any interest or obligation to keep the traditional look of the water mill. In that case only the infrastructure is preserved and repaired (water way, open channel, building, etc.), while the harnessing of the power is achieved by small or very small modern water turbines, appropriate to the available hydraulic fall and flow rate, as the Archimedes screw generator, the Turgo and the Cross-Flow turbines.

The eventuality to replace the water mill by a small hydraulic power plant without keeping any major component of the traditional installation is not examined in the following as it cannot be characterised as refurbishment. The exploitation of such sites must be performed according to the procedure for the dimensioning and design of small or very small hydraulic power plants.

2.3. Principles of fluid mechanics

2.3.1. Introduction to water flow conveyance

The water flow is guided to the water wheel or to the hydraulic turbine by an open channel (or flume) or/and a piping, called penstock in the case of hydraulic plants. In both cases the water conveyance is accompanied by hydraulic losses.

a. Flow in open channels

The water is flowing into an open channel by the gravity. In the case of the uniform and steady flow to a channel of uniform section the force due to the gravity exerted on the water is balanced by the friction forces developed on wetted surfaces. According to that principle the mean flow velocity developed on an open channel of inclination I is expressed by the formula of Manning as $c=\frac{1}{n}R_H^{2/3}I^{1/2}$ where by n is denoted the Manning coefficient, characteristic of the roughness of the wetted surfaces; and by R_H is denoted the hydraulic radius of the wetted channel, defined as $R_H=A/P$ where A is the cross section of the flow and P is the wetted perimeter. For the simplest and more familiar case of an orthogonal cross section (Fig. 2) the hydraulic radius is equal to $RH=\frac{A}{P}=\frac{Bh}{B+2h}$.

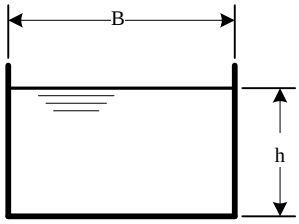


Figure 2: Channel of orthogonal section

An open channel must be designed to operate at the optimum conditions where the flow rate is the maximum for a given inclination. For the case of the orthogonal channel the optimum design corresponds to the operation where the height h of the flow is equal to h=B/2.

The value of Manning coefficient n is given on the following table for some typical materials for artificial open channels

Type of channel	Manning coefficient n
Excavated on earth: gravel	0.022
Excavated on earth: weedy	0.030
Concrete well finished	0.012
Concrete well unfinished	0.014
Planed wood	0.012
Corrugated metal	0.022

The flow rate is therefore equal to $Q = c \cdot A = \frac{1}{n} A \cdot R_H{}^{2/3} \cdot I^{1/2} = \frac{1}{n} A \cdot \left(\frac{A}{P}\right)^{2/3} \cdot I^{1/2}$. In most cases the inclination I is of the order of: I=0.001-0.002.

The mean flow velocity must be higher than 0.3 to 0.5 m/sec in order to prevent the sedimentation of suspended material, the accumulation of which could block the channel.

Example. For an open channel made by planed wood (Manning coefficient n=0.012), of orthogonal section, width B=0.67 m, height of the flow h=0.74 m and inclination I=0.001 by the application of the Manning formula it is obtained R_H=(0.67·0.74)/(0.67+2·0,74)=0.233 m and $c = \frac{1}{n} R_H{}^{2/3} I^{1/2} = \frac{1}{0.012} 0.233^{2/3} 0.001^{1/2} = 1.0$ m/sec. The corresponding flow rate is equal to Q=c·A=1.0·(0.67·0.74)=0.5 m^3/sec=500 l/sec.

b. Flow in pipes

The water is flowing into a pipe under the pressure difference established between the edges. The friction losses, corresponding to energy losses, are distinguished into linear and to singular losses. The linear losses are due to the friction developed between the

flowing fluid and the surfaces of the pipe while the singular losses have mainly the form of kinetic energy losses and they are due to local and sudden acceleration and then deceleration of the fluid.The linear losses are usually expressed by the Darcy-Weissbach formula expressed as $\delta h_L = \lambda \cdot \frac{L}{d} \cdot \frac{c^2}{2g}$; where dh, expressed in mWG, is the losses developed over the length L (m) of the pipe of internal diameter d (m), c (m/sec) the mean velocity of the flow into the pipe and λ the friction coefficient that is dependent on the Reynolds number R_e and the relative surface roughness defined as $\varepsilon_s=\varepsilon/d$, where ε (mm) is the surface roughness of the pipe. By g≈9.81 m/sec^2 the gravitational acceleration is denoted. In more practical application the internal diameter is chosen in order to obtain mean flow velocity of the order of 1 to 4 m/sec (for high flow rates).

The value of the friction coefficient λ can be calculated by the application of the Colebrook-White formula expressed as $\frac{1}{\sqrt{\lambda}} = -2 \cdot \log\left[\frac{2.51}{R_e \cdot \sqrt{\lambda}} + \frac{\varepsilon_s}{3.71}\right]$. The surface roughness of a pipe can be estimated in accordance to the material of the pipe and of the condition. For new steel pipe it can be taken ε=0.1 to 0.2 mm, for pipes from planed wood it is ε=0.1 to 0.2 mm and for concrete pipes ε=0.2 to 0.8 mm.

For the case of fully turbulent flow regime, for example, where Reynolds number is greater than 5·10^5 (that corresponds to almost the totality of practical cases), the friction coefficient depends on the relative surface roughness $\varepsilon_s=\varepsilon/d$. In the following table some indicative values of the friction coefficient are given:

$\varepsilon_s=\varepsilon/d$	0.0001	0.0004	0.0020	0.010	0.0200	0.040
λ	0.0120	0.0160	0.0232	0.038	0.0482	0.065

The singular losses in mWG are expressed as $\delta h_s=\zeta \cdot c^2/2g$ where ζ is the coefficient of singular losses depended on the configuration. For a 90° curve it is of the order of ζ=0.20 to 0.50 while for a valve (or a sluice gate) it is of the order of 0.05 for a fully opened valve to infinity for a completely closed valve.

Example. For a piping made by steel pipes of internal diameter d=0.50 m=500 mm, handling a flow rate equal to Q=1,400 m^3/h=0.389 m^3/sec the corresponding mean velocity of the flow is equal to: $c=Q/(\pi D^2/4)=1.985$ m/sec. Considering that the internal roughness is equal to ε=0.2 mm the relative roughness is equal to $\varepsilon_s=\varepsilon/d=0.2/500=0.0004$. For the case of fully turbulent flow the friction coefficient is equal to λ=0.016 (see above table according to the above the head loss). According to the above for a piping of length L=20 m the corresponding head losses are equal to $\delta h_L = \lambda \cdot \frac{L}{d} \cdot \frac{c^2}{2g} = 0.016 \cdot \frac{20}{0.5} \cdot \frac{1.985^2}{2 \cdot 9.81} = 0.128 \quad mWG$. The linear hydraulic losses can be expressed in dimensionless form per unit of length of the piping. For the above example they are equal to $\delta h_L/L$=0,128/20=0.0064 mWG/m. If at the end of the piping a sluice gate is installed the additional head loss is equal to $\delta h_s=\zeta \cdot c^2/2g=0.05 \cdot 1.985^2/(2 \cdot 9.81)=0.010$ mWG.

Therefore the hydraulic losses developed into the piping are equal to $\delta h = \delta h_L + \delta h_s = 0.128 + 0.01 = 0.138$ mWG.

2.3.2 Principles of hydraulic energy harnessing

The hydraulic energy of water is provided from the gravity and it is expressed as (gH) denoting by g the acceleration of gravity ($g \approx 9.81$ m/sec^2) and H the available head. For example, the difference between the level of headwater and the level of the tail water after the abstraction of the developed head losses.

The principle of hydraulic energy harnessing is shown on figure 3. The flow rate Q of the water is conveyed to the hydraulic turbine by the intake channel and the penstock. As the level difference h is fixed for a given site, it is of interest to dimension the diameter of the penstock as large as possible in order to minimize the head losses δh.

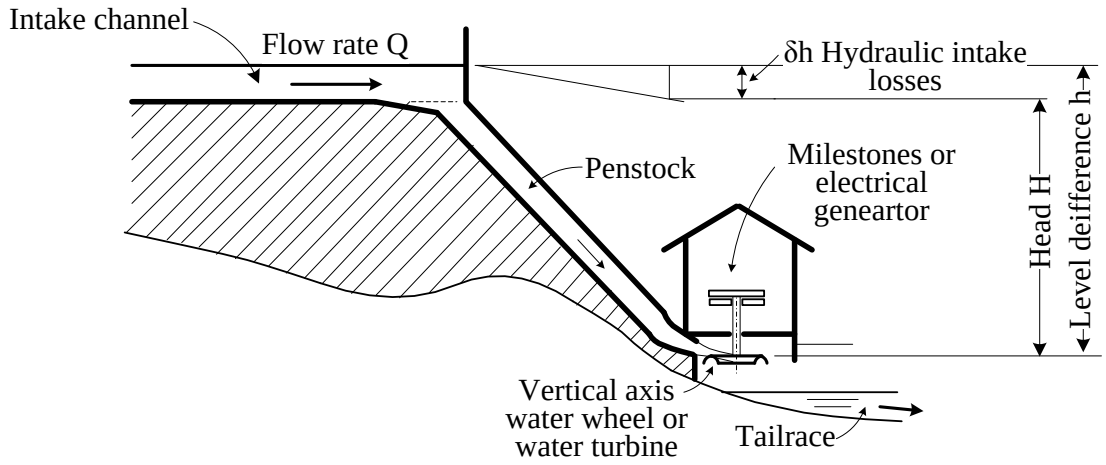


Figure 3: Principle of hydraulic energy transformation to mechanical energy

Example. For the case of the piping considered in the previous paragraph for a site with level difference h between headwater and tail water equal to h=8 m, the available head H is equal to $H = h - \delta h = 8 - 0.138 = 7.862$ m. For example, in the figure above, the hydraulic losses correspond to 1.7% of the head.

Therefore the quantity (gH) expresses the energy per unit mass of the flowing water (in J/Kg in the SI system). Headwater is the spot where water is diverted from his natural way along the watercourse of the river and tail water is the spot where water is driven back to the natural watercourse. Denoting by Q (m^3/sec) the volume flow rate and by ρ (kg/m^3) the density of water, the rate of mass is equal to (ρQ) and according to the above the hydraulic power N_h of the flow rate under a head of H is equal to $N_h = (\rho Q)(gH) = \rho g H Q_{(1)}$. For g=9.81 m/sec^2 and the density of water ρ=1000 Kg/m^3 the above relation takes the form $N_h = 9.81 \cdot H \cdot Q$ in kW (for Q in m^3/sec and H in m).

The conversion of the hydraulic energy to mechanical work is subject to various losses, namely: hydraulic losses (due to friction of the water to solid surfaces), volumetric losses (corresponding to the quantity of water that escapes the energy transformation passing through the gaps outside of the wheel) and mechanical losses (losses of structural elements as the friction in the bearing of the rotating shaft). Taking into account the

energy losses, the overall efficiency η is defined as the ratio of the mechanical power N to the hydraulic power N_h: $\eta=N/N_h \rightarrow N=N_h\eta_{(2)}$. The mechanical power N corresponds to the development of the torque M onto the rotating shaft with angular velocity ω (rad/sec) $N=M\ \omega_{(3)}$ and the angular velocity ω (rad/sec) correlates to the speed of rotation n (rpm) through the equation $\omega=2\pi n/60_{(4)}$.

The torque on the shaft moves the load, the millstones in the case of a water mill. In case that the angular velocity ω_M of the millstones (or of the load in general) is different than that of the wheel, a scaling up transmission element must be introduced, such as belts, chains or more frequently a gear box. Denoting by η_M the efficiency of the transmission system (of the order of η_M=0.90 or more) the toque M_M for the rotation of the millstones is calculated by the equation: $M_M\ \omega_M= M\omega\eta_{M(5)}$.The peripheral speed u_M of the millstone, according to the practice for the grain mills, must be in the range of u_M =7 to 8.5 m/sec$_{(6)}$ so that to best perform the milling action. Taking into account that the diameter of the millstones for technical and practical reasons was of the order of 1 to 3 m (for the mills of Greece the diameter of the millstones was between 0,65 to 2 m), the corresponding speed of rotation of the millstones was ω_M=7.75 to 23.85 rad/sec (n_M=74 to 227 rpm)$_{(7)}$. As the speed of rotation of the millstone n_M depends on the diameter of the millstone and the speed of rotation n of the water wheel depends on the type of the wheel and on the available head H, the transmission system (gear box) must achieve the speed ratio $\lambda=n_M/n_{(8)}$ and must be robust enough to carry the torque M developed on the shaft of the water wheel.

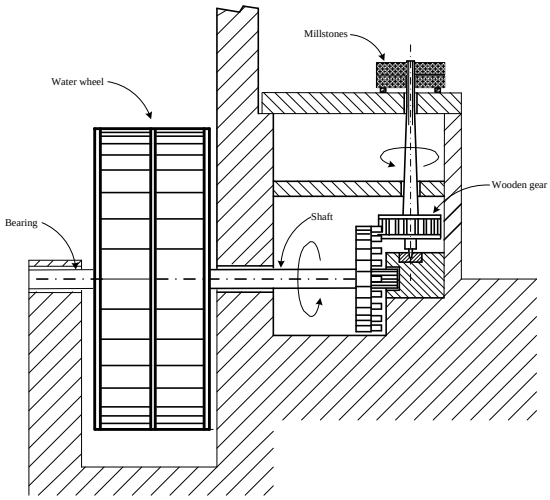


Figure 4: Schematic view of a horizontal axis water wheel and of the transmission system

In figure 4 the transmission system of a horizontal axis water wheel is shown schematically. As the upper millstone rotates around the vertical axis the transmission system is composed a pair of wooden gears in vertical configuration. In that manner the axis of rotations is turned by 90° and the speed of rotation of the millstone is adjusted to the desired value.

2.4. Description and technical characteristics of water wheels

2.4.1. Horizontal axis wheels

a. The overshot water wheel

The overshot wheel is the traditional and the most efficient water wheel, suitable for the exploitation of small steams with low flow rate where a level difference of more than 2 meters is available. The water is supplied via a flume to the buckets of the wheel, and it is gradually collected in the volume formed by the side walls and the buckets. The weight of the water turns the wheel and the water flows out gradually into the tail stream as the wheel rotates fairly to empty the buckets. The weight of the water multiplied by the vertical distance from the axis of rotation corresponds to the development of the torque rotating the wheel and of the mechanical power. The supply of water to the wheel is regulated by a hand-operated sluice gate. The water wheel itself must be clear of the tail water. The overall efficiency of the overshot water wheel is in the range of 60 to 80%.

The peripheral speed of the wheel is equal to $u=\omega D/2$, where $\omega=2\pi n/60$ is the angular rotation speed. The velocity of water entering the buckets is equal to velocity c_1 resulting from the action of the sluice gate and the gravity. In order to achieve the best possible filling of the buckets with water and therefore the optimum operation of the wheel the peripheral speed u of the wheel must be of the order of magnitude of the velocity c_1. This is the rule for calculating the speed of rotation of the overshot wheel, which can be estimated from the empirical relation $n=\frac{21}{\sqrt{D}}$ (rpm) where D is the diameter of the wheel in meters (Fig. 5).

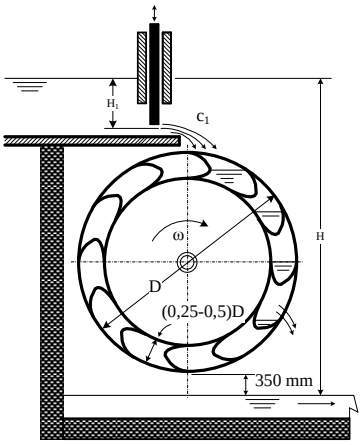


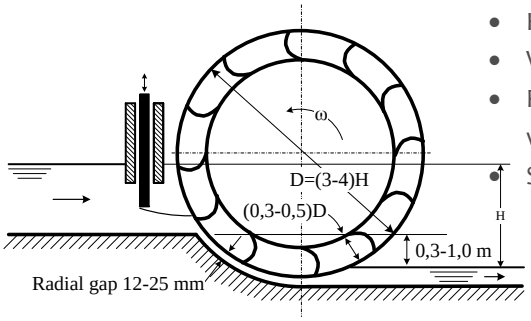
Figure 5: Schematic configuration and dimensions of overshot water wheel

- Head: H=3 to 10 meters.
- Water velocity in flume: c≈1,0 m/sec.
- Water velocity at the exit of the sluice gate: $c_1 \approx$ 2-3 m/sec corresponding to H_1=0.3-0.6 m.
- Flow rate Q=75-150 l/sec per meter of flume width.
- Width of the wheel 0.35 m larger than that of flume.

According to fluid mechanics the mean value of the velocity c_1 at the exit of the sluice gate is of the of the order of $c_1 \approx \sqrt{2gH_1}$ denoting by H_1 the head upstream of the sluice gate (Fig. 5). The flow rate to the water wheel is therefore equal to the fluid velocity c_1 multiplied by the rectangular area below the sluice gate.

b. The undershot water wheel

The undershot wheel is a horizontal axis wheel, similar to the overshot wheel, rotated under the action of the water striking the paddles or blades at the bottom of the wheel (Fig. 6). Compared to the overshot wheel the undershot wheel needs less civil work for the installation (as the water is driven to the bottom of the wheel). It is therefore cheaper but the overall efficiency is lower, varying from 60 to 70%. The flow rate and therefore the power output, is regulated by a sluice gate located in the flume just upstream the wheel. Under the action of the sluice gate the velocity of the water striking the wheel is increased, transforming that way part of its hydraulic energy to kinetic energy. The speed of rotation n of the undershot wheel can be estimated from the relation $n=\frac{9c}{D}$ (rpm) where c (m/sec) the velocity of the water into the flume and D (m) the diameter of the wheel.



- Head: H=0.5 to 3 meters
- Water velocity in flume: c≈1,0 m/sec
- Flow rate Q=300-900 l/sec per meter of flume width
- Speed of rotation 2-12 rpm

Figure 6: Schematic configuration and dimensions of undershot water wheel

A variant of the undershot wheel is that called stream wheel when the bottom of the flume is (almost) horizontal (Fig. 7). The paddles of the wheel are pushed by the flowing water that is decelerating. The radial extension of the paddles is greater than the depth of the water into the flume. The mechanical energy on the stream wheel is provided by the kinetic energy of the water. This type of wheel is less efficient than the typical undershot wheel.

The power abstracted by the flowing stream is equal to the difference of kinetic energy $N_h=\rho Q(c_1^2-c_2^2)/2$ denoting by ρ the density of water and by Q the flow rate through the wheel. The mechanical power developed on the shaft is equal to $N=N_h\eta$ denoting by η the overall efficiency with a maximum value of the order of $\eta_{max}=30\%$.

The optimum operation of the stream wheel occurs when the downstream velocity c_2 into the flume slows down to $0.5c_1$, denoting by c_1 the mean velocity upstream. The optimum speed of rotation of the wheel corresponds to a peripheral speed $u=\omega D/2u$ equal to 0.67 of the upstream water velocity c_1.

For a flume with depth of water upstream equal to 1 m and velocity $c_1=1.5$ m/sec the corresponding mechanical energy is equal to 0.40 kW per meter of width of the wheel.

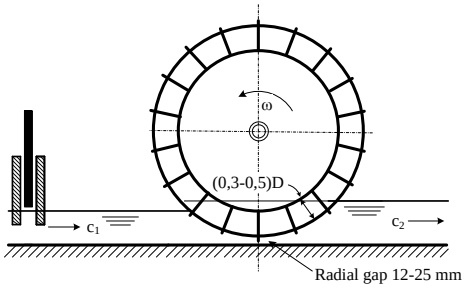


Figure 7: Schematic configuration and dimensions of undershot stream water wheel

c. The breastshot water wheel

A more efficient version of the undershot wheel is the breastshot (or midshot) wheel, in which the water is fed into the wheel a bit less than half-way up (Fig. 8). The flume driving the water is curved to follow the curvature of the wheel forming a radial gap in the range of 12 to 25 mm, minimizing the leakages. This shaped flume is built by concrete, cement-rendered brick, steel plate or even wood. Provision must be made to filter out all water-borne debris that is could harm the wheel paddles.

Breastshot wheels are less efficient than overshot wheels but more efficient than undershot wheels. The blades of the breastshot wheel have the profile of buckets, as those of most overshot wheels, and not the profile of simple paddles like those of most undershot wheels.

The speed of rotation of the breastshot wheel can be estimated by the application of the same relation valid for overshot wheels.

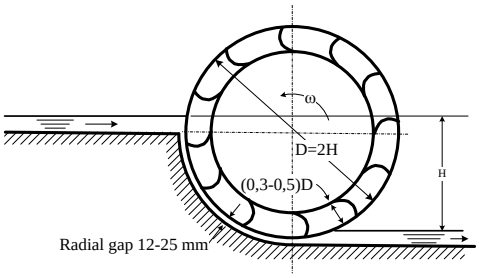


Figure 8: Schematic configuration and dimensions of breastshot water wheel

- Head: H=0,5 to 3 meters
- Water velocity in flume: 1,0 m/sec
- Flow rate Q=300-900 l/sec per meter of flume width
- Speed of rotation 2-12 rpm

d. Example of dimensioning of overshot type water wheel

For the case of the open channel taken in the example of part 2.3.1.a. it was width B=0.67 m, height of the water h=0.74 m, mean velocity c=1 m/sec and flow rate Q=0.5 m^3/sec=500 l/sec. Considering that the mean active head upstream of the sluice gate is equal to H_1=h/2=0.335 m (Fig. 2), the speed of the water downstream of the sluice gate (part 2.4.1.a.) is of the order of $c_1 \approx \sqrt{2gH_1} = \sqrt{2 \cdot 9.81 \cdot 0.335}$=2.5 m/sec.

If the available head H is equal to H=3 m, for the case of an overshot water wheel the diameter of the wheel must be of the order of D=H=3.0 m. The radial extension of the buckets is of the order of 0.30 D=0.9 m. Taking into consideration a margin of 0.35 m, the

overall width of the wheel is equal to B'=B+0.35=1.0 m. The speed of rotation of the wheel is equal to $n=\frac{21}{\sqrt{D}}=\frac{21}{\sqrt{3}}$=12.1 rpm.

Considering the overall efficiency equal to η=0.7 after the application of relations (1), (2), and (3) the mechanical power and the corresponding torque are calculated:

- the mechanical output power N=10.0 kW and;
- the corresponding torque on the shaft of the wheel M=8,128.7 and Ntm=828.6 kpm.

2.4.2. Vertical axis water wheels

a. Description of the vertical axis wheels

The vertical axis water wheels operate as action turbines and their shape and mode of operation is similar to the modern hydraulic turbine well known as Turgo turbine. More specifically water is driven to the wheel by a circular or conical pipe. At the end of the pipe a conical nozzle is shaped and therefore, water exits in the form of a jet with high velocity (Fig. 9). In that way the head H of the water is transformed to kinetic energy. The jet is directed to the perimeter of the water wheel with an inclination α of the order of $\alpha=20^{o}$. As the jet hits the buckets of the wheel, its direction changes, resulting to the development of a peripheral force into the buckets. This peripheral force finally induces the torque developed on the shaft and consequently hydraulic energy is converted to mechanical.

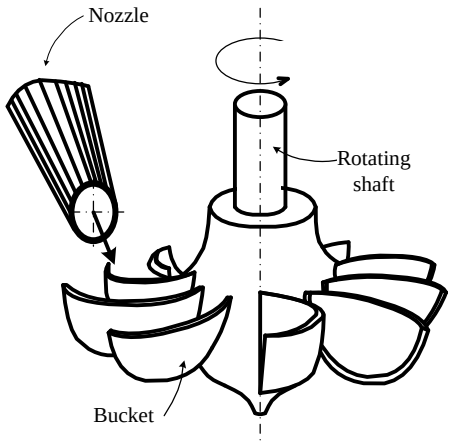


Figure 9: Schematic configuration of vertical axis (action) water wheel

The head, which is equivalent to the energy of the water per unit of mass or of volume, for vertical axis wheels is usually between 6 and 8 m, though values from 4 to 12 m are also reported. The diameter of the wheels is of the order of 1 to 1.5 m while the diameter d of the nozzle varies from 5 to 10 cm.

The efficiency of the vertical axis wheel can be as high as 0.80 for a good design of buckets, while the curve of efficiency versus the flow rate is very flat.

The operating characteristics of the majority of the vertical axis water wheels are: flow rate from 100 to 200 m^3/h, head from 6 to 8 m and mechanical power of 1.5 to 3.0 kW. The speed of rotation of the runner is of the order of 50 to 150 rpm.

b. Operating characteristics of vertical axis water wheel

Denoting by d the diameter of the jet (of the order of magnitude of the diameter of the nozzle) and by c the mean velocity of the water in the jet, the flow rate is equal to $Q=cA_{(13)}$ where $A=\pi \cdot d^2/d$ is the cross section of the jet. The mean velocity of the jet is provided from the conversion of head H to kinetic energy; therefore, $c=\varphi\sqrt{2gH}_{(14)}$ where $\varphi \approx 0,97$ a loss factor.

According to the theory, the optimum peripheral speed u of the wheel is equal to half the velocity of the jet $u=\omega D/2=0,50c_{(15)}$.

c. Example of operating characteristics of vertical axis water wheel

- The head H is equal to H=6 m, the diameter of the nozzle d=6 cm, and the inclination angle of the jet α=200.
- According to the above inputs, the following operating characteristics are concluded:
    - Mean water jet velocity: c=10.524 m/sec.
    - Water flow rate: Q=0.0297 m3/sec=29.7 l/sec=107.12 m3/h .
    - Peripheral velocity of the wheel: u=4,94 m/sec.
- For a wheel with a diameter D=1.20 m the corresponding speed of rotation is: n=78.62 rpm
- Assuming an overall efficiency η=0,80 after the application of relations (1), (2), and (3) the mechanical power and the corresponding torque are calculated:
    - The mechanical power output: N=1.4 kW.
    - The torque developed on the shaft: M= 170.04 Nm=17.33 kpm.

2.5. General technical characteristics of water wheels

On the diagram of figure 10, in the head-flow rate axis, the operating range of various types of water wheels is given, useful for the selection of the appropriate type of water wheel for a given head and nominal flow rate. On the same diagram, the selection range of Cross-Flow, of VLH (Very Low Head) as well as of the Archimedes screw generator are given. Cross-Flow hydraulic turbine is a type of action turbine applied in SHP plants. It is manufactured for power ranged from some kW to 1 MW.

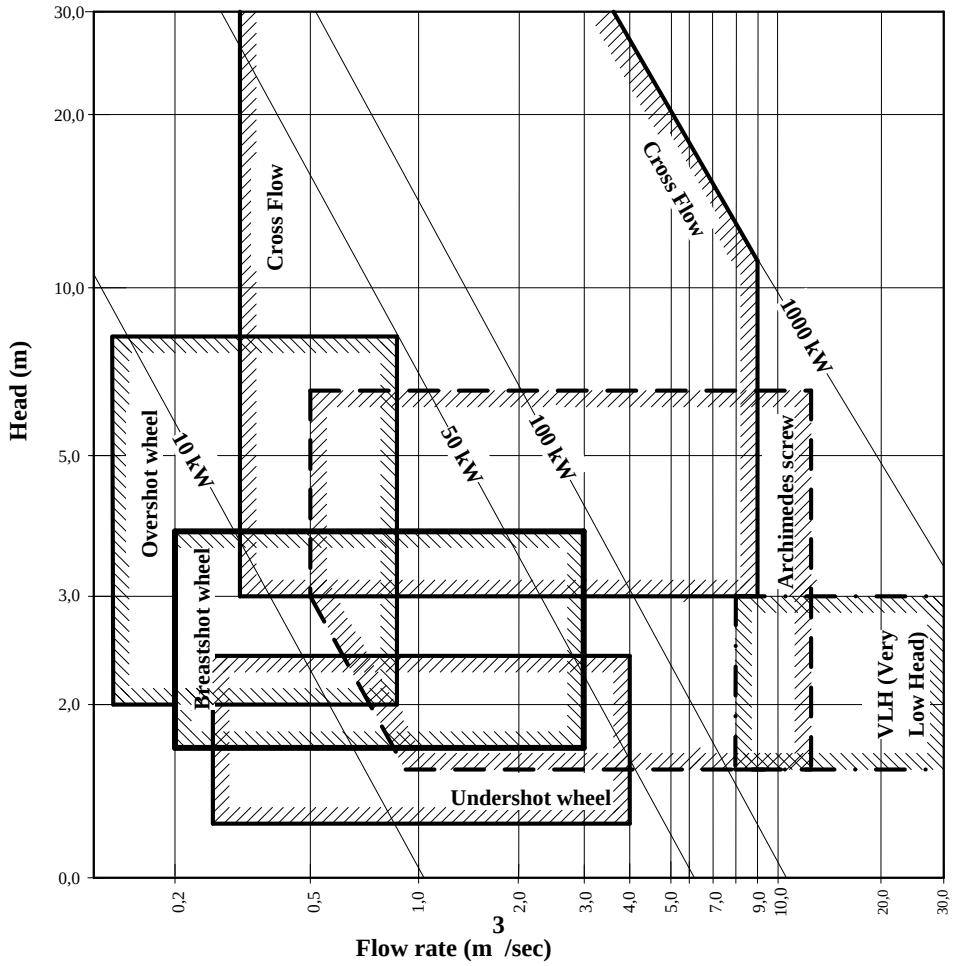


Figure 10: Selection diagram of the traditional water wheel and of Cross-Flow, very low head turbine and Archimedes screw generator

Archimedes screw generator is practically the old Archimedes screw pump operating in the reverse mode as water turbine (in the appendix 2.10. more detailed presentation of the Archimedes screw generator as well as of the Cross-Flow turbine is given.) The types of turbines, Cross-Flow and VLH (Axial-Flow propeller) and Archimedes screw, are presented in a common diagram with the traditional water wheels as, to our opinion, they are the most appropriate hydraulic turbines to replace the traditional water wheel, if that is permissible and desirable during the refurbishment of a water mill.

Figure 11 provides the efficiency curves of water wheels as a function of load along with the corresponding curves for modern hydraulic turbines (Francis, Cross-Flow and Axial-Flow turbines), for comparison purposes (Schnitzer V. and Gross W. 1993). It can be seen that the efficiency curve is quite flat over a wide range of load variation. However, the efficiency of modern hydraulic turbines is in general higher. The overshot water wheel is the more efficient one, compared to the other horizontal axis water wheels types (breastshot and undershot).

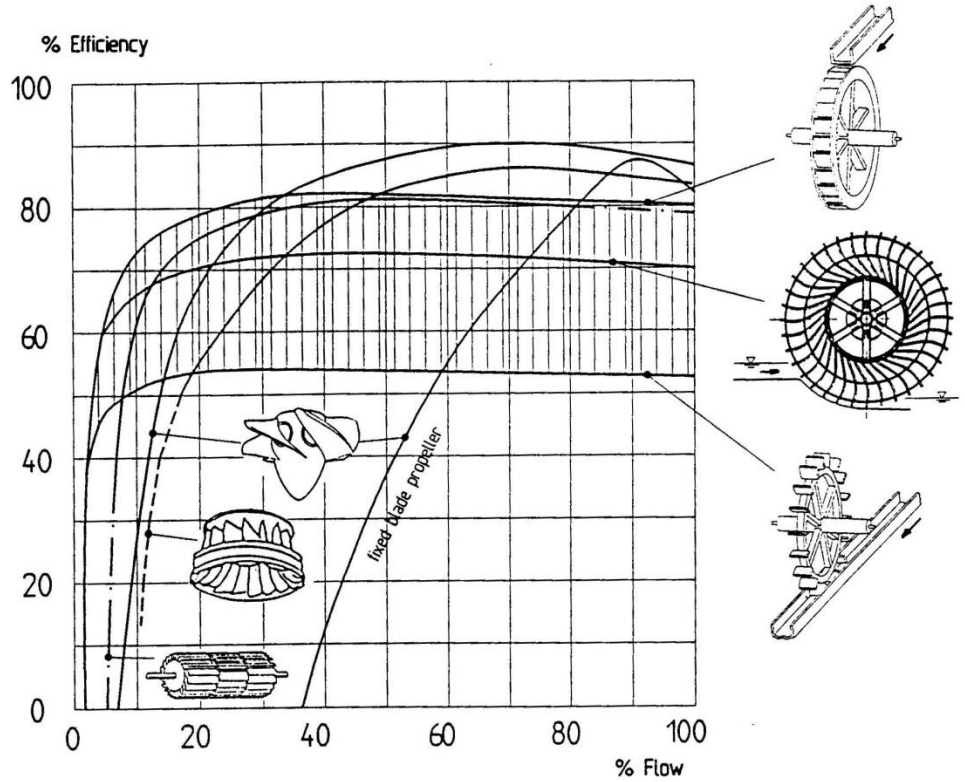


Figure 11: Efficiency of water wheels with load variation. Comparison with modern hydraulic turbines (Cross-Flow, Francis and Axial-Flow)

According to the above description the diameter of the wheel is proportional to the available head H while the width of the wheel is proportional to the available flow rate.

The main disadvantage of water wheels is their low speed of rotation resulting in heavy and bulk constructions, robust enough to sustain the weight corresponding to the wheel itself and to the contained water, and the developed torque. On the other hand, maintenance and repair is a simple and easy task. In addition, water wheels do not suffer from cavitation or debris contained into water.

The speed of rotation of horizontal axis water wheels ranges from 6 rpm for large wheels, up to 20 rpm for the small ones. For the vertical axis (action type) water wheels speed is higher, usually in the order of 60-100 rpm. This range of speed of rotation is fine to drive a standard mile-stone as no speed multiplication is needed for the case of vertical axis water turbines. Besides, for the case of horizontal axis water wheels the necessary multiplication ratio (of the order of 4 to 6) is achieved by a wooden gear with wooden teeth. Nevertheless, the speed of rotation of the wheels is unsuitable when coupled with a generator for electricity production; since the speed of rotation is commonly of the order of 1,500 rpm (lower synchronous speed generators are more expensive). Therefore a system for the multiplication of the speed of rotation must be introduced, such as a gear box, a V-belt or even a chain transmission.

For structural strength reasons of the wheel it is recommended to keep the ratio of the width B to the diameter D of the wheel not greater than 0.625 ($B \leq 0.625D$). The upper limit reported is $B=2D$. Beyond this value the strength of standard-sized timbers and other structural elements must be oversised so that to sustain the weight and the forces

developed. In the case of large flow rates, resulting into a large width B of the wheel, the stiffness of the construction can be improved by the insertion of reinforcing rims across the width.

2.6. General lay-out of the water mills installations

The operation of water mills, as described earlier, is based on the conversion of the energy of the water running in a free stream to mechanical work. Therefore the water stream, partly or entirely, is guided to the water wheel, by a water conveyance system.

Two configurations of water conveyance systems can be identified; that of deviation of the water stream from the natural bed of the stream and that of guidance of the water stream, partly or in total, to an open channel where the water velocity is high. The second one, as shown in figure 12, is appropriate for the stream water (undershot) wheel (Fig. 7). The natural stream is guided by a separator wall to an open channel and then to the water wheel. Upstream of the water wheel an intake gate is located by which the flow rate to the wheel is stopped when the mill is out of operation. Adjacent to the water wheel the building where the mill, the millstones etc. are housed, is erected.

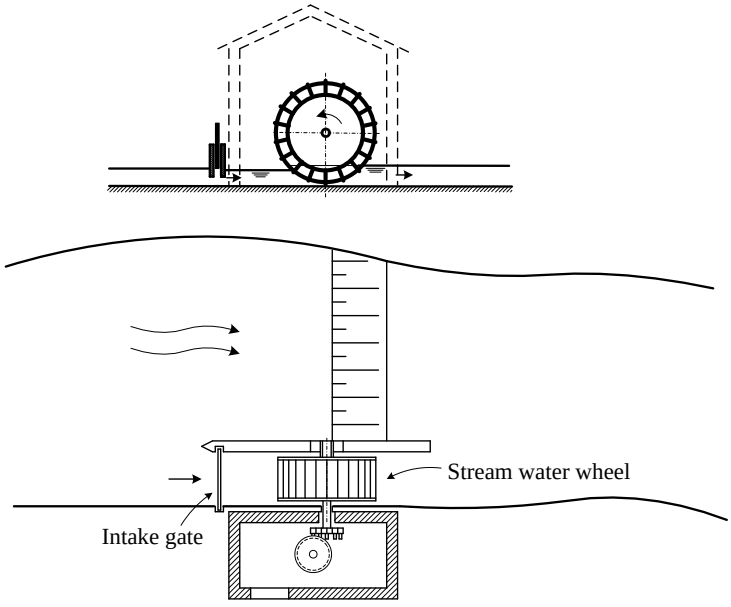


Figure 12: Water conveyance systems for stream water wheel

The deviation configuration of the water conveyance systems is shown schematically in figure 13. This configuration is appropriate for all other types of water wheels of horizontal axis. The head H of water, that is the water level difference between upstream z_1 and downstream z_2 of the water wheel, is generated by a weir erected in the natural water course of the stream. An open channel starts just upstream on the weir by which the water of the natural stream can be conveyed to the lower level downstream, after passing through the water wheel. The length of the channel depends on the topography of the area; it could be very short, as in the case of figure 12 (the head H is generated only by the weir) or of the order of a hundred meters. In that case, the head H is generated by the weir and the inclination of the natural bed of the stream. At the beginning of the

channel an intake gate is placed, in order to control the flow to the water wheel. When it is closed, no flow rate is directed to the water wheel and the natural stream overflows the weir following the initial bed of the stream. When the gate is open, the natural stream can flow, partly or entirely, through the deviation channel to the downstream level. At the end of the intake channel a strainer or a screen is installed, indispensable for almost all the water wheels, appropriate to withhold objects that could eventually harm the water wheel. Just upstream of the water wheel a sluice gate is located by which the flow rate to the water wheel, and therefore the produced mechanical output power, is regulated. The water after passing through the water wheel joins the natural bed of the stream via the tailrace.

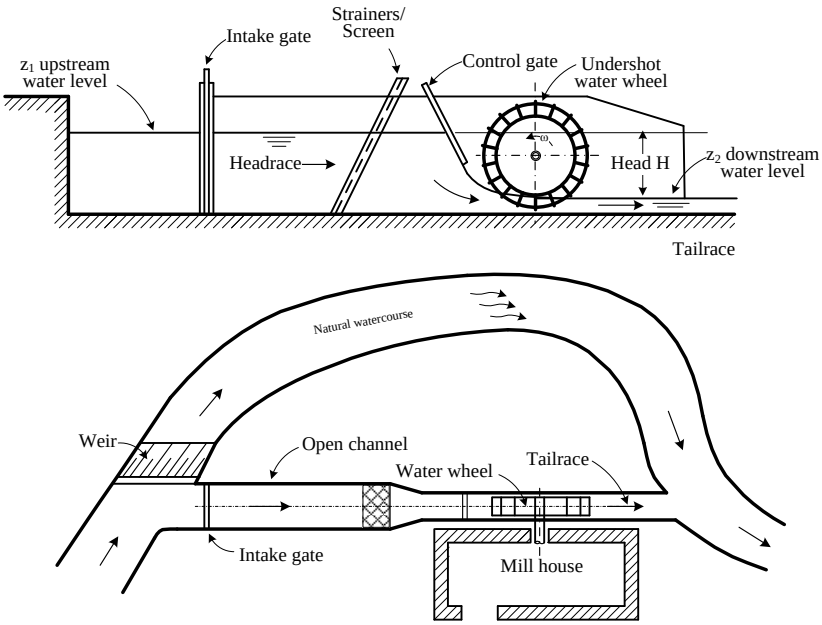


Figure 13: Water conveyance systems for horizontal axis water wheel

The figure 14 gives a typical lay-out of water conveyance system for the case of vertical axis water mill which is appropriate for relatively elevated values of the head. Water is guided to the nozzle through an open channel and then via the penstock. At the entrance of the penstock a screen is appropriately installed. The vertical axis water wheel is housed under the floor of the building, while the vertical shaft moves directly the millstones, without any need of alteration (increase) of the speed of rotation by the introduction of a gear box. In traditional vertical axis turbines the flow from the nozzle to the runner is controlled manually by a wooden stick plugged in at the end.

In regions with intermitted supply of running water (if water streams is the usual climate characteristic), as in the case of Greece, a water reservoir is built upstream of the penstock (by stones and slush grout), of adequate capacity to assure continuous operation of the mill certain hours daily. In cases where the topography of the area is convenient, a pond is formed by constructing a dam with a spillway instead of water reservoir, as shown in figure 10b for the case of an overshot wheel.

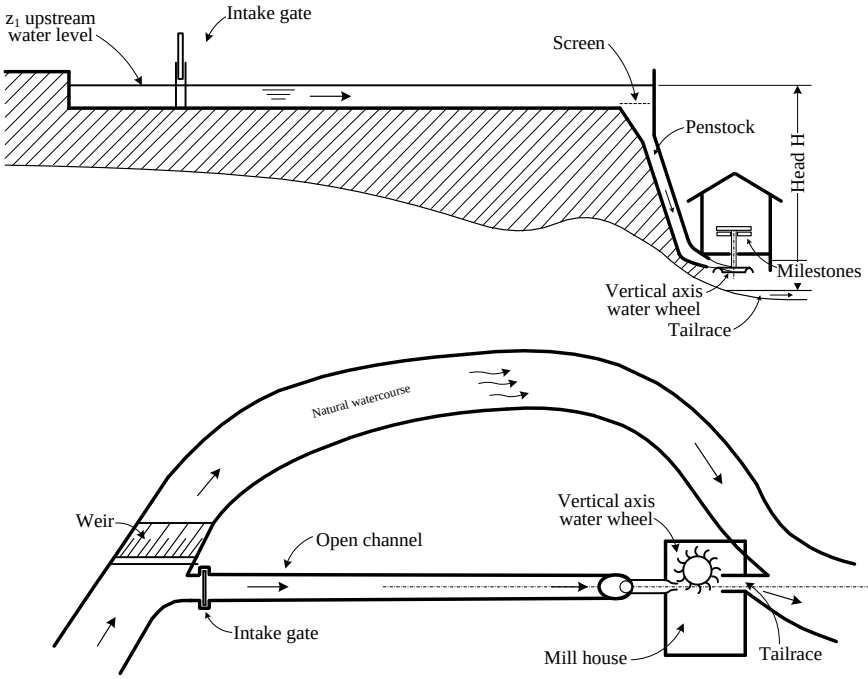


Figure 14: Water conveyance systems for vertical axis water wheel

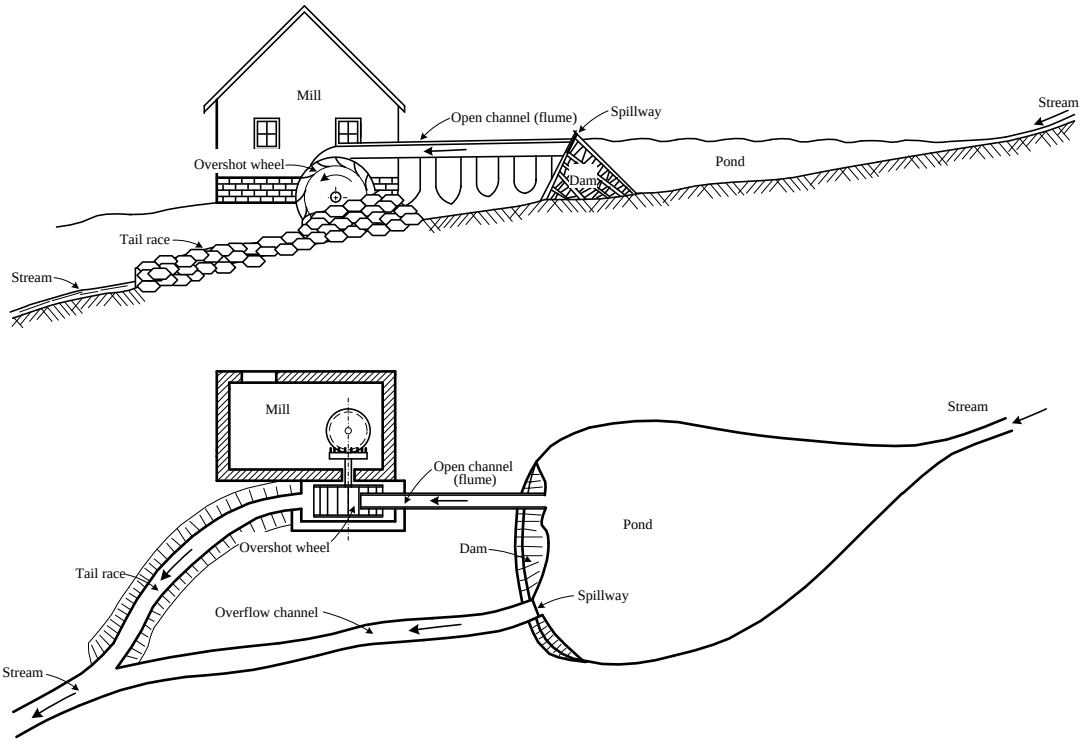


Figure 15: Water conveyance systems for horizontal axis water wheel with the formation of a pond by a dam

2.7. Technical actions for the reactivation of water wheels to produce electricity

2.7.1. Introduction

The traditional old wheel mills were designed in order to cover exact energy needs, conforming to the technical means and know-how of the time of construction. According to the precedent analysis, the mechanical output of the old wheels was limited to about

2 to 5 kW for the case of water mills for grains treatment, and was of the order of 30 to 40 kW for paper mills. The reactivation of a traditional site must be designed and performed without major intervention for scaling up the power output, an action that could cause major negative social reactions, although keeping the traditional look of the buildings and of the sites.

Due to the limited power output, the reactivation and renovation of a traditional water wheel for electricity production must be faced as an action to generate some income, from the energy sales, sufficient to offset the O&M cost of the equipment. Taking into consideration that the electromechanical equipment (i.e.: water wheel, generator, switch panel, etc.) are very reliable and long life devices, the combined action of renovating a traditional water mill site with a simultaneous power generation capable to ensure the necessary income for maintenance, could be economical viable and with a high degree of acceptance from the environmental and social point of view.

The technical interventions to be carried out in order to reactivate a traditional water wheel should be focused on the following:

- The water conveyance elements and flow rate control devices.
- The identification of the condition of the building, especially the element relative to the installation of the electromechanical equipment (needed space, weights etc.).
- The selection of the electromechanical equipment (renovation or replacement of the water wheel, gear box, electrical generator, switch panel and control etc.) and the formulation of the technical specifications.

2.7.2. Repair of the water conveyance system

According to the description of the water conveyance systems of the water wheel installations, the sections that might need repair, maintenance or even replacement are:

- The open intake channel as well as the tailrace channel. Objects accumulated must be removed while the surfaces of the channel (initially from stone of cement) must be inspected and repaired.
- The intake gate must be inspected and probably replaced by a modern gate with manual or electrical operation. In figure 16 the view of a gate on an open channel is illustrated. It is equipped with hand wheel for manual operation (Fig. 16a) and by an electric motor with chain for the automatic remote operation.
- The screen or strainer must be inspected, maintained or replaced.

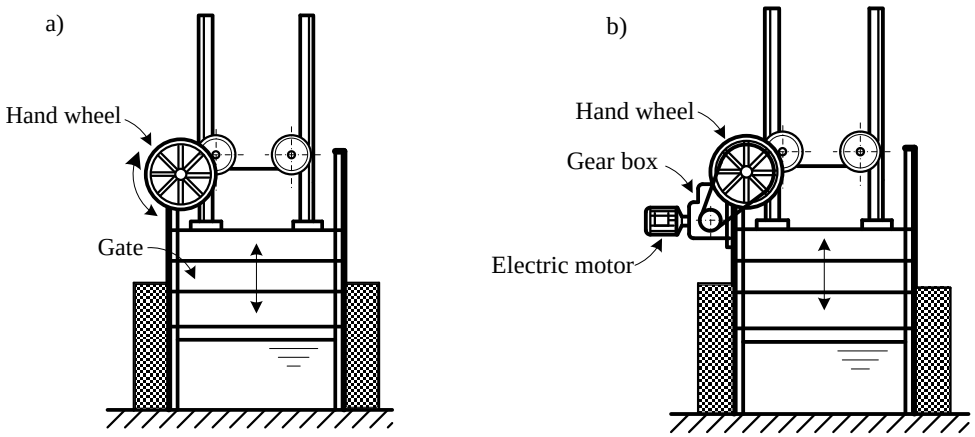


Figure 16a, 16b: Sluice gate on the open channel a) with hand wheel for manual operation b) with hand wheel and electrical motor and chain for automatic and remote operation

2.7.3. Repair or replacement of the water wheel

Water wheels and the components of the mills were initially constructed by wood according to the know-how, the materials and means of the construction period and the region. Even the shaft and the bearings were made of wood. Later, around the end of 18th century, water wheel and the other components of the mill were fabricated from iron, sheets or profiles, although wooden constructions continued to be used. All this key equipment may become unserviceable and need replacement after some years of suspension, exposed to the humidity and corrosive weather conditions, either fabricated by wood or by iron sheets and metallic rods.

In mills equipped with horizontal axis water wheel, the wheel is positioned outside the building and dominates, due to the remarkable size, in the general view of the site. If the wheel is completely unserviceable it must be replaced by a similar wheel, of the same type and the same outside dimensions but constructed by modern material and elements, as the shaft and the bearings of the shaft. In the interior of the building the old traditional devices (shaft, gears, pulleys, millstones), if existed, cannot anymore be used for electrical energy production, but can be restored and exhibited.

In water mills of vertical axis water wheel, which is the majority of mills in Greece, the initial wheel was constructed by wood and later by metal sheets. Figure 12 shows an overview of vertical axis wheels of various designs and fabricated by wood or metal sheets. All wheels have similar general aspect, and their evolution was the runner of Turgo turbine, as shown into the frame of figure 17. For the reactivation of the water mill for electrical energy production, the initial vertical axis wheel must therefore be replaced by an equivalent Turgo type runner. It must be noticed that the vertical axis wheel is located under the floor of the house; it is not visible and has moderate dimensions. Consequently the replacement of the initial wheel by a Turgo type runner of modern design will not alter the character and the view of the site.

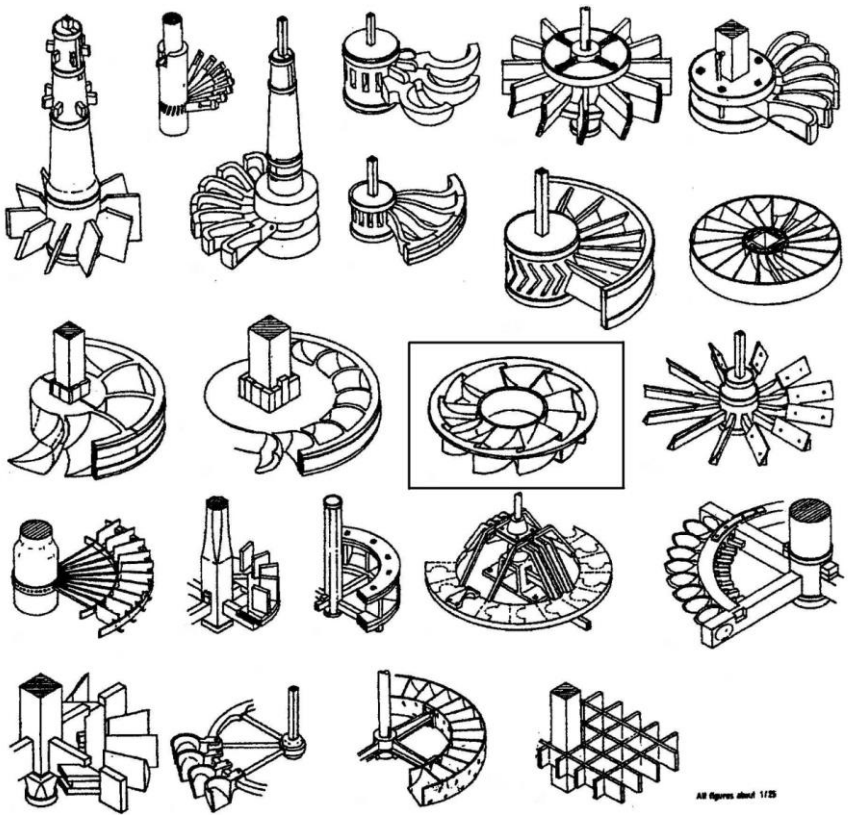


Figure 17: Various types of vertical axis water wheels. The wheel into the frame is similar to modern runner of Turgo turbine (according to B. Moog, 1994)

2.7.4. Introduction of electromechanical equipment

a. Mechanical Power Transmission

In order to produce electrical power the shaft of the wheel must be coupled to a gear box. The output shaft of the gear box should be coupled to the electric generator. As the nominal power of the wheel is small (in the range of 2 to 5 kW for the wheels processing grains and 30 to 40 kW for the wheels of paper mills), the modern electromechanical equipment is of small size and could be easily hidden in an old-fashioned box made of wood. In that way the modern electromechanical components will not be visible and the general view of the installation remains unchanged.

This device for the multiplication of the speed of rotation is heavy, costly and needs maintenance because of the high transformation ratio and of the considerable torque developed on the shaft of the wheel (primary shaft). According to the examples given in sections 2.4.1. and 2.4.2. the speed of rotation of the horizontal axis wheel is of the order of 12 rpm, while the speed of rotation of a vertical axis wheel of 80 rpm. Therefore, for the same output power the torque on the axis of the wheel (primary shaft) is about 6.7 (≈80/12) times higher in the case of horizontal axis wheel compared to that of the vertical axis wheel. Taking into consideration that the mechanical power will be transformed to electricity by a generator, working in general around 1500 rpm (the most common market available variant) the multiplication ratio should be of the order of 125:1 for horizontal axis wheels and of 19:1 for vertical axis wheels.

The transmission of mechanical power (torque on the rotating shaft) with the simultaneous increase of the speed of rotation can be achieved with gears or pulleys of chains or belts.

In old times gears with wooden teeth were used as a standard transmission configuration of the first stage. This equipment, even if it is occasionally still operational, cannot be applied for electricity generation as the speed of rotation of millstones was much lower than that of the electric generator. Therefore this old equipment must be replaced either by a system with pulleys of chain or of belt, as schematically shown in figure 18, or by a gear box, as shown in figure 19. In the case demonstrated in figure 18 the multiplication transmission ratio achieved by the pulleys is of the order of 8:1, not sufficient enough for coupling the electric generator directly to the secondary pulley. It is therefore necessary to introduce a gear box, the transmission ratio of which must be of the order of 15 (considering that the overall transmission ratio is equal to 125:1).

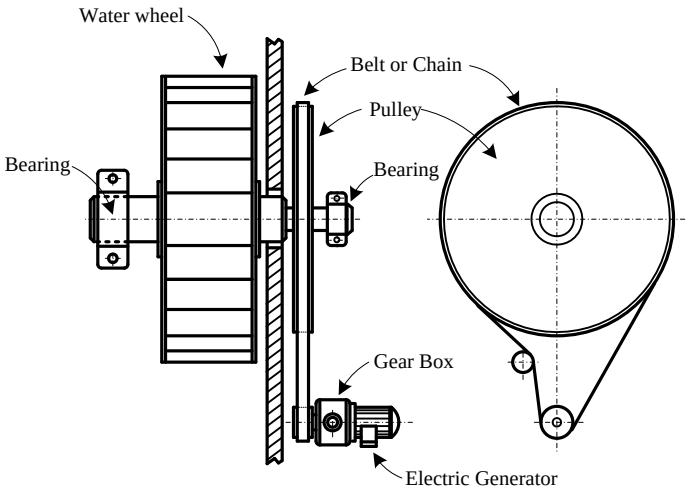


Figure 18a: Mechanical transmissions with pulleys of belt or of chain

In figure 18b the introduction of an electrical generator and torque transmission by a pair of pulleys and flat belt is given for the case of a mill equipped with horizontal axis wheel. The first pulley is divided in two parts in order to be inserted to the shaft of the wheel, without any other intervention to the original system. The electrical generator is coupled with the secondary pulley by a coupler and eventually a gear box in order to achieve the desired multiplication of the speed of rotation. According to this configuration the mechanical energy of the wheel can used either for milling operation (in that case the belt is removed or simply the generator is not connected to the grid) either for electricity production (in that case the upper millstone is lifted from the lower in order to rotate freely).

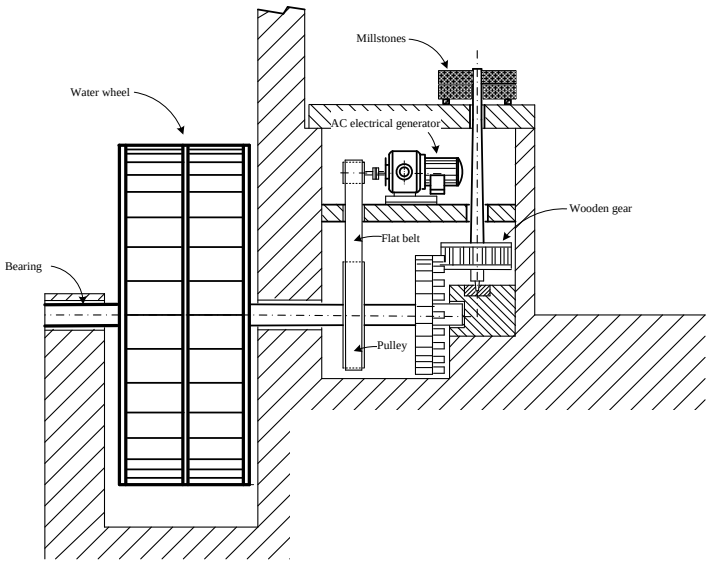


Figure 18b: Introduction of pulleys and electrical generator to a horizontal axis wheel while the mill remains operational

It must be pointed out that the electric generator is of very small size compared to the water wheel or the pulley. In figure 19 the primary shaft of the water wheel is coupled to a typical spur gear box, while the secondary shaft directly to the generator. In figure 20 the primary shaft is coupled with a planetary gear box which is more appropriate for high transmission ratios. Due to the high transmission ratio and the high torque in the primary shaft, the matching gear box for the above application is not a quite standard device. The main difference between spur and planetary gear box is that the planetary is smaller in size (and therefore cheaper) but has lower efficiency than the equivalent spur gear box.

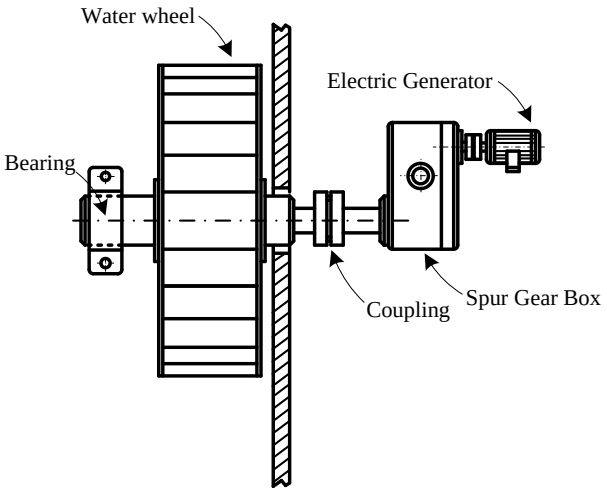


Figure 19: Mechanical transmissions with spur gear box

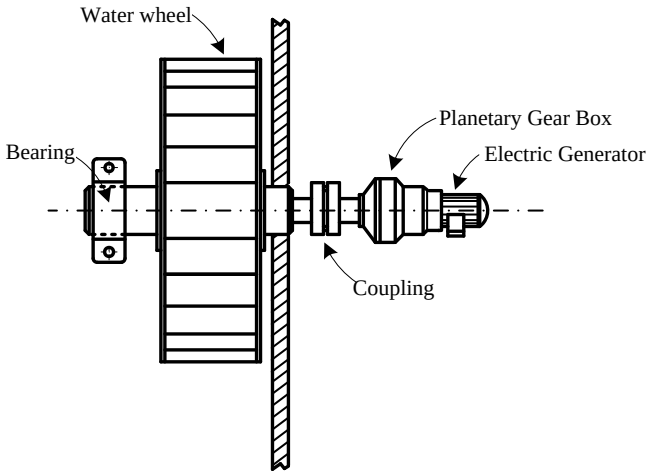


Figure 20: Mechanical transmissions with planetary gear box

Figure 21 shows a 130 years old retrofitted water mill in UK that was refurbished and renovated for electrical energy production (http://www.powerpal.co.uk/pposhotpwr.html). A spur gear box and an asynchronous (induction) generator were installed. It concerns the case of an overshot water wheel, with a diameter of 6 m. From the picture one can notice the considerable size of the spur gear box (weight 350 kp), compared to the size of the electric generator (weight 100 Kp).

Figure 21: Photo of an overshot water wheel of 6 m renovated for electric energy production

In figure 22, the introduction of electrical generator and torque transmission by a pair of pulleys and flat belt is given for the case of a mill equipped with vertical axis (Turgo type) wheel. The first pulley is divided in two parts in order to be inserted to the shaft of the wheel, without any other intervention to the original system. The electrical generator is coupled with the secondary pulley by a coupler and eventually a gear box in order to achieve the desired multiplication of the speed of rotation. According to this configuration the mechanical energy of the wheel can used either for milling operation (in that case the belt is removed or simply the generator is not connected to the grid) either for electricity production (in that case the upper millstone is lifted from the lower in order to rotate freely). The electrical generator is located on the floor of the mill and

the only modification needed is a hole on the floor of the mill house for the flat belt. The wheel could be the initial of the mill or it can be replaced by a modern one designed in order to achieve higher performances. The components shown on figure 22 are designed in scale taking into consideration the typical size of the vertical axis wheels.

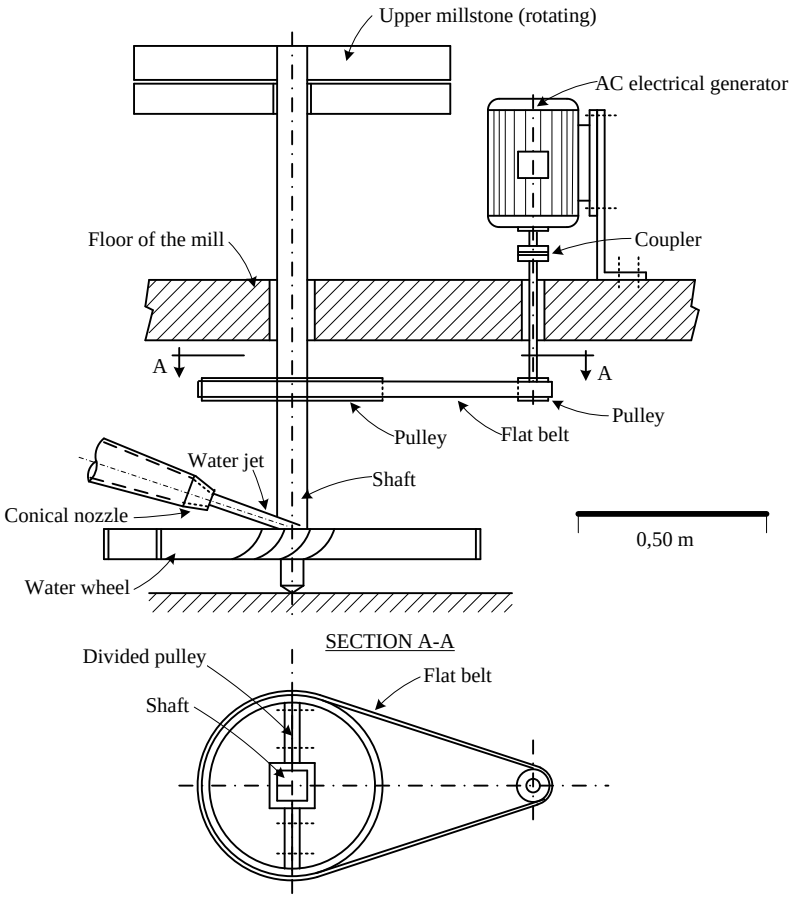


Figure 22: Introduction of pulleys and electrical generator to a horizontal axis wheel while the mill remains operational

b) Equipment for electric power production

The mechanical energy generated by the secondary shaft (torque on the rotating shaft) is converted to electricity and transferred to the electrical grid. The conversion of mechanical power to electricity is done by an electric generator, while for feeding this energy to the grid an electrical panel is used. For the small nominal power (of the order of 2 up to 30-40 kW) of concern, the size of the generator running at 1500 rpm (four pole generator) is very small and it is a standard and relatively low cost device. If the generated electric power is fed to an existing grid, the most appropriate type of generator is the asynchronous (induction) generator, otherwise a synchronous generator must be provided. Asynchronous generator is cheaper and simpler in the maintenance but of lower efficiency than the synchronous one.

The electrical panel comprises the fuses, switches, metering and safety devices etc. which constitutes standard and low cost components. The overall size of the electrical

panel is very small (of the order of 0.8X0.60X0.30 m) and it can be easily fixed on a side wall.

2.8. Technical plan for reactivation of water wheels to produce electricity

The restoration of a water mill in order to adapt the mechanical equipment to produce electricity should retain the general view of the plant, including the building and the water conveyance system (water channel, water shaft), and should not cause any additional unwanted environmental impacts. In this context, the minimum requirements and steps of a technical plan are listed below:

a) Site survey.

- Site selection based on its globally estimated hydraulic potential, the energy demands, and any further exploitation plans of the project (i.e. touristic).
- Identification of site and land ownership. A need for leasing agreement or the establishment of share schemes with the community might be possible.
- Examination of potential limitations related to ecological acceptability of conflicts with existing or potential users of the water (priority rights).
- Execution of preliminary topographical survey in order to define access conditions and identify existing roads.

b) Hydrological study.

- Elaboration of a hydrological study in order to estimate with accuracy the availability of the necessary for the operation water flow. From these data the operating hours per year and the produced electrical energy can be estimated. The hydrological study will be elaborated after the collection of existing data or the application of a flow prediction method, or the execution of simple measurements of the water flow.

c) Economic feasibility study.

- Assessment of the electricity production: utilisation, and of electricity cost/tariff, during the project life-time.
- Assessment of the plant construction cost and time scale and of the operation and maintenance costs.
- Outline one or more engineering design options (i.e. runner type, size or number) and assessment of the corresponding costs and energy production.
- Assessment of other benefits and possible incomes of the project (i.e. touristic exploitation).

d) Licensing and planning.

- Obtain required licenses, depending on the specific legislation in each country, for the plant operation and connection to the grid.

- Detailed time schedule of operations from engineering design to commissioning stage.

e) Engineering design and construction.

- Completion of civil engineering works (if needed: weir, intake, silt basin, spillways, channels, power housing, site accessibility, etc.).
- Repair and refurbishment of water conveyance installation, consisting of the water channel and the vertical water shaft (for the vertical axis mills) by the installation of new and efficient water filters, electrical driven gates and valves for the water control.
- Replacement of the nozzle tip of the water shaft with a modern nozzle equipped with a valve for the flow control.
- Replacement or repair of the wheel (runner) with a new runner of modern design and increased efficiency. For the case of vertical axis turbines, the new runners could be standardised as the operating characteristics are similar to all cases.
- Installation of a gear box by which the low speed of rotation of the runner will be multiplied (by 10 times approximately) in order to move the electrical generator. The gear box could be of a standard type.
- Selection and installation of the electrical generator. In case that the electrical energy produced is fed to an interconnected grid, the generator could be asynchronous. These solutions correspond to simpler control needs of the plant, it is cheaper but must be accompanied by a power factor correction.
- Selection and installation of electrical and control panel of the plant.
- Connection to the grid.
- Program for education of the personnel for the operation and maintenance.

f) Plant commissioning and test run.

- Trial operation of the unit for certain period to apply monitoring and O&M training procedures.

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2.10. Technical plan for mills restoration appendix

In modern applications the hydraulic energy is transformed to mechanical (torque on the rotating shaft) and then to electrical energy which is the form of energy particularly appropriate for the transmission and consumption. The analysis and description in the following considers the case that the electrical energy produced by small hydroelectric power plants, supplies an existing and robust electrical grid, as it usually happens nowadays.

In the following appendices a short description of the electromechanical components that are indispensable for the transformation of the hydraulic energy to electrical energy is given (sections 2.10.1. and 2.10.2.). The type and the size of components presented are appropriate for the refurbishment of traditional water mills in order to produce electricity.

Also, in sections 2.10.3 and 2.10.4 two types of hydraulic generators that of Archimedes screw and Cross-Flow are described.

2.10.1. Generators and electrical switchgear

a) Introduction.

Commonly, the electrical energy has the form of three-phase alternating current that is characterised by the voltage V (Volts), the current I (A) and the frequency f (Hz). Coupling the turbine with the electrical generator, the system runs at the speed of rotation in which the (moving) torque developed on the shaft of the turbine equals the (braking) torque developed on the shaft of the generator, being proportional to the electrical power supplied to the grid. In accidental cases, when no torque is developed on the generator, resulting by an electrical fault (as in the case of a short-circuit), the speed of rotation increases rapidly up to the runaway speed. The runaway speed in all cases of turbines, even in those of waterwheels, is of the order of 1,8 to 2 times higher than the nominal speed of rotation. The operation of the system at runaway speed is a quite alarming incident as it stresses the rotating masses due to the increase the centrifugal forces (proportionally to the square of the speed of rotation). The risk from the over-speed is that the windings of the generator can be spun off the rotor under the

effect of centrifugal forces. For the case of hydroelectric plants it is common to have a specially strengthened generator where the windings are specially fixed on the rotor. Also, it is a good practice to have an over-speed sensor that stops the water intake as soon as possible in order to prevent the full development of the over-speed or to limit the duration of this alarming situation. According to the above mentioned a commercial normal generator in general may not be able to withstand the over-speed at runaway conditions.

The synchronous speed of rotation n_S (rpm) of the generators rotor is related with the frequency f (Hz) of the alternating current by the relation $n_S=60f/p$ denoting by p(-) the number of pole pairs. In continental Europe the frequency f is fixed at 50 Hz. As the pole pair p is an integer the possible synchronous values of the speed of rotation are given in the following table for f=50 Hz.

p(-) Number of pole pairs	n_S (rpm) Synchronous speed of rotation
1	3 000
2	1 500
3	1 000
4	750

As the mechanical power N_M at the input of the generator is equal to the torque M multiplied by the angular velocity ω (rad/sec)=(2πn/60), N=Mω, for the same mechanical power N the torque M, and therefore, the size and the cost of the generator increases as the speed of rotation is lower. On the other side the selection of higher speed of rotation correspond to a less rigid generator that needs more maintenance and supervision.

Generators transform mechanical energy into electrical energy, in three phase alternating current. Depending on the characteristic of the network supplied the producer can choose between synchronous and asynchronous generators. Synchronous generators are used in the case of isolated load networks or wherever the unit has a significant influence on the network. In some particular cases, asynchronous generators may also be used. In the case of large networks, both types of generators can be used.

In the case of a direct current (DC) generator, it can be envisaged only in the case on very small nominal power (of the order of 1 kW) and for applications as the battery charging. If necessary a braking system (either air or oil operated) should be considered to the rotating system.

b) Synchronous generators.

They have alternating current n the three phase armature winding (normally in the stator) and direct current in the field winding (normally in the rotor). With the rotor rotating at the synchronous speed, its direct current field flux establishes a rotating field on the stator that rotates at the same speed, corresponding to alternating current of the

nominal system frequency f. The field flux is generated by the control current I_f of the field coils, associated with a voltage regulator to control the output voltage at the terminal of the machine.

The synchronous generator is started-up unexcited and driven by the hydraulic turbine from standstill to nominal speed. The field excitation is applied at around 95% nominal speed, while the voltage V is controlled to the nominal (no load value) by adjustment of the control current I_f of the field winding. The machine is synchronised (the voltage of the generator and of the supplied electrical grid are in phase and of the same magnitude) by controlling the speed and phase angle via the turbine wicked gate control (the nozzle opening valve for action turbine or the gate opening for horizontal axis wheel) and with the automatic voltage regulator for fine voltage adjustment. Once the generator is connected to the grid the system voltage imposes a reference to its operation.

The power factor cosφ, denoting by φ the angle between the vector of voltage and the vector of current, can be controlled by adjusting the control current I_f. The operation of an asynchronous generator under an isolated grid and the achievement of voltage and speed (i.e. frequency) regulation in very narrow limits is performed either by precise wicket gate control or the introduction of ballast loads. In these operating conditions the generating unit (hydraulic turbine and electrical generator) is provided with flywheels of sufficient inertia of rotating masses to absorb the power fluctuations of the load, compensating the response time of the wicket gate reaction.
The exciting current for the synchronous generator is supplied by the exciter. Two types of exciters are used, namely the rotating and the static exciter. The rotating exciter is a small DC generator that it is driven by the main shaft. The power absorbed by the DC generator amounts to 0.5-1.0% of the total generator power. The static exciter is a grid connected rectifier that provides DC current to the generator field coils. Static exciters are robust, easy to maintain, they have very good response to the generators voltage oscillations and have high efficiency.

Typical values of the overall efficiency of synchronous generators are as follows versus the nominal output power

Rated power (kW)	Max. efficiency η_G (-)
10	0.910
50	0.940
100	0.950
250	0.955

c) Asynchronous generator.

An asynchronous generator is simple squirrel-cage induction motors with no possibility of voltage generator and operating at a speed of rotation related to grid frequency. The mains supply defines the frequency of the stator rotating flux and hence the

synchronous speed. The actual speed of rotation of the rotor is higher than the synchronous and the difference increases as the load of the generator increases (at the synchronous speed of rotation no torque and consequently no electrical power is generated). The difference between the actual speed of rotation n (rpm) with the synchronous n_S is expressed in dimensionless form by the slip factor s defined as $s=(n_S-n)/n_S$.

The variation of the developed torque in relation with the slip factor is given in figure A1, as the torque (and the load) increase the (absolute value of the) slip factor increases also up to a maximum value above which the generator is undersised for the applied mechanical torque.

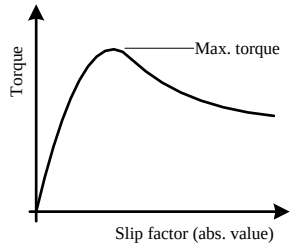


Figure A1: Slip factor versus the torque for asynchronous generators

The asynchronous generator draws its excitation current from the grid, absorbing reactive energy by its own magnetism. They cannot generate when disconnected from the grid because they are incapable of providing their own excitation current. The power factor cosφ of the generated electrical current it is not controlled and therefore a bank of capacitors is needed to compensate the absorbed reactive energy and correct the value of the power factor. Despite the above mentioned disadvantages they are used in the case of small nominal power as they are simpler in construction, cheaper and require less maintenance than synchronous generators. The efficiency can be of the order of 95% for a 100 kW machine and reach the value of 97% for an output of 1 MW. In general efficiencies of asynchronous generators are slightly lower is lower than the corresponding values of synchronous generators.

On start-up the turbine is accelerated to a speed slightly above the synchronous speed of the generator when a velocity relays closes the main switch with the line.

Asynchronous generators are selected in the case of the nominal power below 1 MW and only when they supply a stable grid where their output constitutes a very small portion of the power system load.

The operating voltage of the generator increases with power. The standard generation voltages of 400 V or 600 V allow for the use of standard distributor transformers as outlet transformers and the use of the generated current to feed into the plant power system.

d) Comparison between synchronous and asynchronous generators.

In conclusion, before making the decision on the type of generator to be used, it is important to take into consideration the following points:

- A synchronous generator can regulate the grid voltage and supply reactive power to the network. It can therefore be connected to any type of network.
- An asynchronous generator has a simpler operation, requiring only the use of a tachometer to couple it to the grid. As the machine is coupled to the grid there is a transient voltage drop, and once coupled to the grid the generator absorbs reactive power from it. For the correction of the power factor, if needed, a capacitor bank is necessary. The efficiency of an asynchronous generator is generally lower than that of the synchronous of a synchronous one.

Standardised or upgraded (in order to increase the robustness against over speed) mass-produced machines should be used in all cases for the refurbishment of waterwheel installations. Usually mass-produced machines are designed for lower over speed values (typically 1.25 to 1.50 times the rated speed) while in the case of hydraulic turbines and waterwheels higher values of the over speed can appear on runaway conditions.

Climatic conditions (ambient temperature, altitude, humidity, etc.) can affect the choice of the class of insulation level, the temperature rise and finally the cost.

e) General remarks.

Generators can be manufactured with horizontal or vertical axis, independently of the configuration. A flywheel is frequently used to smooth–out speed variations and assist the turbine control. Especially for the case of horizontal axis waterwheel, the inertia of the waterwheel, by virtue of the size of the wheel, is estimated to be sufficient and no additional flywheel will be needed.

Another criterion that must be into consideration for the specifications of the generator is the bearings and their arrangement. For example it is common practice to install a generator with extra-reinforced bearings supporting the runner in cantilever (the forces developed on the runner due to the running water or the proper weight of the runner are undertaken by the bearings of the generator. The cantilever configuration of the shaft of the generator cannot be applied in the case of the horizontal axis waterwheel because of the insertion of the speed multiplication device (gearbox or belt with pulleys). The cantilever configuration can be examined only in the case of the vertical axis waterwheel while for the case of horizontal axis waterwheel their size and weight is very high to be supported by the bearings of the generator.

The cooling system of very small generators, as in the cases examined, is an open cooling circuit with atmospheric air. This system, compared to the closed circuit with air-water heat exchanger, is very simple, corresponds to low cost but the generator needs more frequent cleaning and maintenance.

e.1) Switchgear equipment.

The electricity supply regulations place a statutory obligation on the electric utilities to maintain the safety and quality of electricity supply within specified limits. The independent producer must operate his plant in such a way that the utility is able to fulfil its obligations. Therefore various electrical devices are required inside the powerhouse for the safety and protection of the equipment and of the supplied grid.

Switchgear must be installed to control the generators and to interface them with the grid or with an isolated load. The generator breaker, either air or vacuum operated, is used to connect or disconnect the generator from the power grid. Switchgear is also equipped with the necessary measurement instruments and the associated instrument transformers. Most of the measured values are introduced as inputs to the control unit by which the generator voltage, power factor and other parameters are continuously adjusted following the changes of the load or of the hydraulic energy.

The protection of asynchronous generator must include, among other devices a reverse-power relay giving protection against motoring (operation of the generator as an asynchronous motor absorbing electrical energy from the grid), differential current relays in order to prevent internal faults in the generator stator winding, a ground-fault relay providing system backup as well as generator ground fault protection. The protection of power transformer (if existed) includes an instantaneous over-current relay to protect the main transformer when a fault is detected in the bus system or an internal fault in the main power transformer occurs.

The independent producer is responsible for earthing arrangements within his installation. This must designed in agreement with the public utility.

e.2) Automatic control.

Small hydro schemes are normally unattended and operate through an automatic control system. In general the automatic control is more extended and elaborated as the nominal power of the plants increases. For very small plants the control must simply ensure that the installation and equipment will not be damaged under any detected malfunction. In general the following requirements from the automatic control system must be examined:

- The system must include the necessary relays and devices to detect malfunctioning of a serious nature and then act to bring the unit or the entire plant to a safe de-energised condition.
- Relevant operational data of the plant should be collected, registered and available for making relevant operating decisions and stored in a data base for the evaluation of the plant performance.
- An intelligent control system should be included to allow for full plant operation in an unattended environment.
- It must be possible to access the control system from a remote location and override any automatic decisions.

The automatic control system must be configured in modules: an analogue to digital conversion module for measurement of upstream water level, wicket gate (or nozzle position), instantaneous power output, temperatures etc. as well as a telemetry module providing the interface for offsite communications, via dial-up telephone lines or other communications technologies. This modular system approach is well suited to the widely varying requirements, equipment standardisation and continuous technological development. In addition, the modular system favours cost reduction and ease of maintenance. Taking advantage of the enormous development of desktop computer many manufacturers supply standardised data acquisition system. New and cheap peripheral easily connected to a laptop or a smart phone can be used for the monitor and replace control equipment in the event of failure. Due to the rapid development of digital technologies the differences between hardware platforms such as PLC, micro-controllers and PC or laptops, disappear for the operator while the cost diminishes continuously.

Immediate tripping is required for the case of over-current, earth fault, maximum or minimum voltage, power reversal and over/under frequency. In cases of elevated stator temperature, low oil level in the bearing sump, high bearing temperature or high cooling air temperature may have an alarm which annunciates the problem, but in any case, in the absence of corrective action, tripping will eventually follow.

The instruments and devices generally recommended for monitoring and protection are as follows: voltmeter, ammeter, wattmeter, energy meter, power factor meter, tachometer, hours in operation counter, synchronizer (in case of synchronous generator), water level or pressure indicator (for the case of vertical axis waterwheel), emergency stop device, short-circuit current protection, overcurrent protection, reverse power relay, frequency monitor, voltage monitor, bearing monitor.

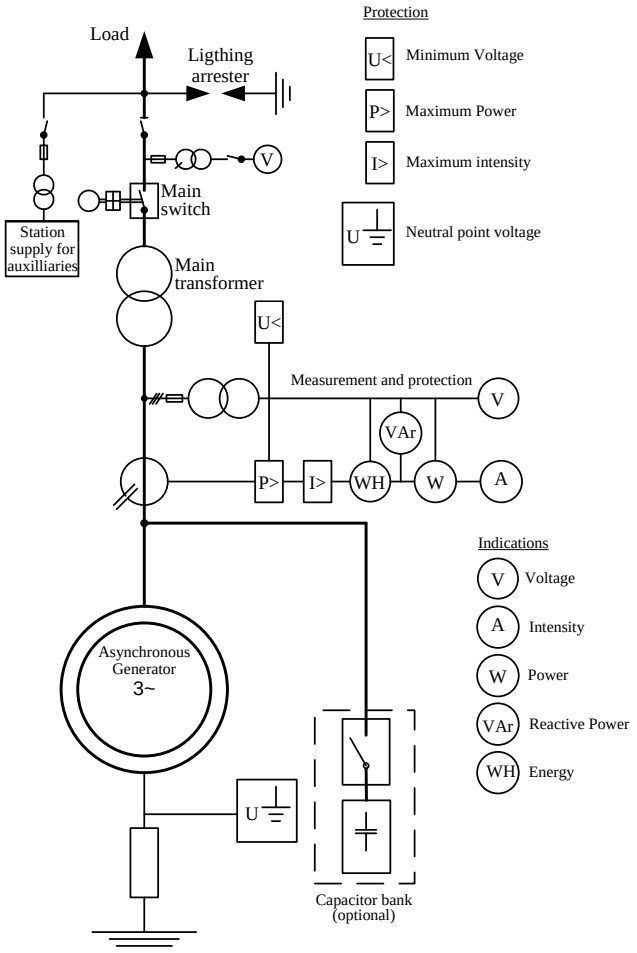


Figure A2: Single line diagram-Asynchronous generator

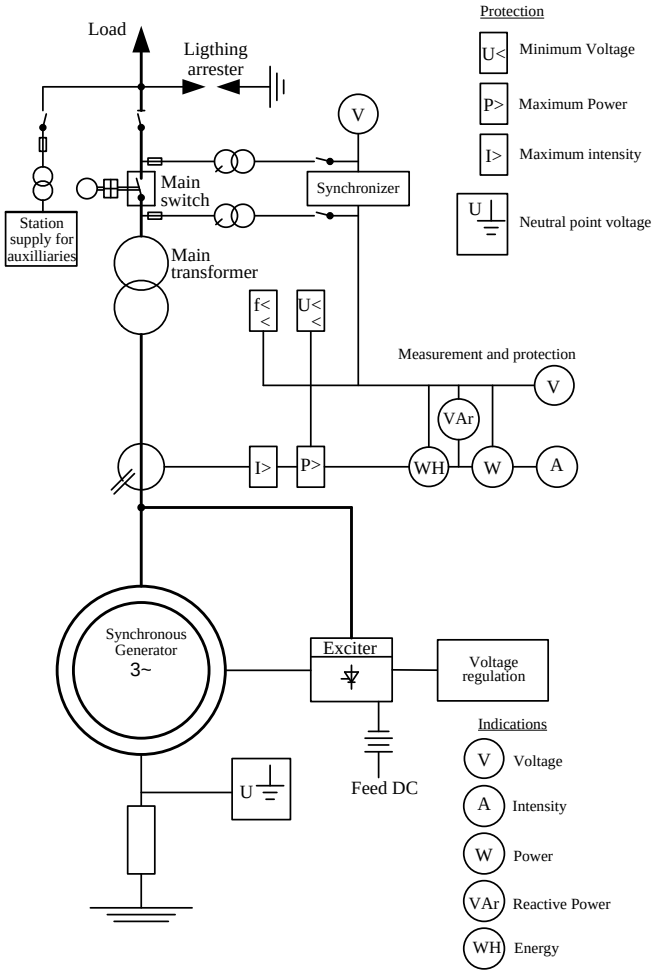


Figure A3: Single line diagram-Synchronous generator

Depending on the site, two types of controls can be considered:

- local (near to the item to be monitored or protected) or;
- remote (distant from the item to be monitored, situated inside or outside the plant).

In both cases the best solution from the point of simplicity and effectiveness should be chosen. More precisely the automation should be as simple as possible to avoid breakdowns. It shall be designed for easy replacement of wearing parts (use modular elements). In the figures A_2 and A_3 typical single line diagrams are given for asynchronous and synchronous generators.

e.3) Measurement of the headwater level.

Particular attention must be drawn to the measurement and recording of the headwater level and secondary of the tailwater level. In plants provided with automatic control the best solution is to use transducers connected to the data acquisition system and the computer. The sensor for measuring of the water level is located at the measurement position of the water stream, while the processing unit is usually located into the well protected and easily accessible for operation and service location of the powerhouse.

There is a wide range of sensors for the measurement of the water level based on a variety of measuring principles. It must be realised that the point of the level measurement must be selected carefully in order to obtain a representative measurement (uniform velocity distribution, far from recirculations or flow singularities). The level sensor can be based on the hydrostatic principle or even on ultrasonic technology. In order to prevent that the submergible pressure sensor does not risk to be damaged by floating material, it is located into a well.

In the case of the lateral open channel drawing water to a waterwheel the measurement of the headwater channel maybe omitted and only a level switch, located upstream of the intake gate, can be sufficient for the automatic operation of the hydroelectric plant: if the level into the channel is below a fixed limit (indicating that there is not enough water to assure the operation) the intake gate remains closed and the plant is out of operation. The water intake gate remains closed in case of emergency or any malfunction of the system. In case of very high headwater level, in order to prevent the damage of the water wheel two possibilities can be examined: either the gate valve closes and the waterwheel is driven to stop or the gate valve opens up to a fixed limit corresponding to a maximum flow rate that ensures the safe operation of the waterwheel.

f) Technical data of standardised electromechanical equipment.

In the following technical data and main dimensions of standardised equipment are given, taken from the catalogue of manufacturers. These data could be useful in the initial steps of the selection of the equipment and of the dimensioning of the plant.

f.1) Synchronous generators.

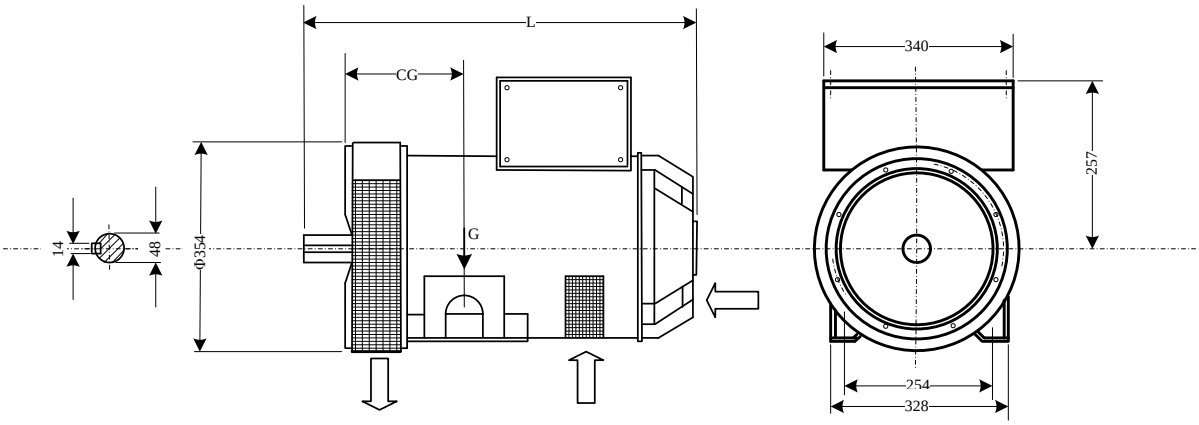
In the following table the main operating characteristics are given for standardised asynchronous generators designed for industrial application and for nominal power from 12 to 75 KVA (as it is difficult to find standardised synchronous generators of very small size specially designed for small hydropower plants), with 4 poles (speed of rotation n=1500 rpm) and low voltage (400 V). In the same table the efficiency is given at the nominal operating point. The rated outputs refer to an installation up to 1000 m asl and to a maximum ambient temperature of 40°C. For higher altitudes and higher maximum temperature correction factors must be taken into consideration. The standard degree of protection IP 23 is provided for air-to-air cooling system.

Industrial application/low voltage

4 Poles, 400 V, 50 Hz – 1500 rpm IP23

Type	Leads	Power rating (KVA)				Efficiency 4/4 pf=0.80 125/40 %	Inertia J (Kg m²) (approx.)	Weight G (Kp) (approx.)
		Temp. rise/Ambient temp (°C)						
		Continuous duty		Stand by				
		125/40	105/40	163/27	150/50			
160 XA4	12	13.5	12.5	15.0	14.0	84.0	0.106	106
160 SA4	12	16.0	15.0	17.5	16.5	84.1	0.128	117
160 SC4	12	23.0	20.4	25.0	24.0	84.9	0.165	136
160 MA4	12	28.0	25.5	30.5	29.5	87.5	0.205	152
160 MB4	12	32.0	29.1	34.8	33.7	87.0	0.230	168
200 SA4	12	42.0	37.1	46.0	44.5	87.2	0.369	247
200 SB4	12	50.0	45.0	55.0	53.0	88.2	0.424	254
200 MA4	12	60.0	53.0	66.0	61.0	88.7	0.488	278
200 MB4	12	75.0	68.7	82.0	79.0	90.0	0.615	325

The main dimensions are given in the following tables for horizontal orientation and double bearing arrangement.



Double bearing 160 frame size

Dimensions (mm)					
160	XA	SA	SC	MA	MB
L	533	533	571	651	651
CG	185	195	210	230	255

Double bearing 200 frame size

Dimensions (mm)				
160	SA	SB	MA	MB
L	695	695	785	785
CG	185	195	210	230

f.2) Asynchronous generators.

In the following data the main operating characteristics are given for standardised asynchronous generators specially designed for small hydropower plants of nominal output from 55 to 2000 kW, with 4 poles (speed of rotation n=1500 rpm) and 6 poles (n=1000rpm). In the same table the efficiency is given the efficiency versus the partial load. The available voltage is 380 up to 690 V. The rated outputs refer to an installation up to 1000 m and to a maximum ambient temperature of 40° C. For higher altitudes and higher maximum temperature correction factors must be taken into consideration. The standard degree of protection IP 23 is provided for air-to-air cooling system.

Standard generators are supplied with grease lubricated rolling bearings that are usually oversized in order to guarantee a minimum lifetime of 100,000 hours of operation. Generators can be equipped with a special shaft extension to directly connect the hydraulic turbine runner. In this configuration all bearings and the shaft are designed to withstand the axial and radial loads developed on the runner. Rotors are dynamically balanced. Generators can be supplied with reduced (R) or special (S) vibration level on request.

Asynchronous generators/Insulation Class F-IP23-IC 01
4 Poles 1500 rpm 50 Hz

Power Pn KW	Type	Speed rpm	Voltage Vn V	Current In A	Torque Tn Nm	Efficiency (%) 4/4	3/ 4	2/4	Power factor 4/4	3/ 4	2/4	Inertia J Kg m²	Weight Kg	Max overspeed rpm
55	250S4	1 535	400	92	372	92.0	92.0	90.5	0.86	0.84	0.79	0.50	275	3 000
75	250M4	1 520	400	126	509	92.5	92.3	91.0	0.86	0.83	0.75	0.80	350	3 000
90	280S4	1 520	400	148	608	93.0	93.0	92.0	0.88	0.86	0.79	0.90	405	3 000
110	280M4	1 520	400	181	743	93.0	93.0	92.0	0.88	0.86	0.79	1.10	445	3 000
132	315S4	1 520	400	214	883	93.9	94.3	94.1	0.89	0.88	0.84	1.70	570	2 750
160	315MA4	1 520	400	263	1 067	94.2	94.5	94.1	0.88	0.87	0.81	2.10	705	2 750
200	315MB4	1 517	400	328	1 332	94.5	94.9	94.6	0.88	0.87	0.83	2.50	750	2 750
250	315MD4	1 517	400	401	1 656	95.0	95.3	95.0	0.90	0.88	0.83	3.10	850	2 750
315	315ME4	1 517	400	506	2 085	95.1	95.2	95.0	0.90	0.88	0.83	3.30	930	2 750
315	355LA4	1 510	400	511	2 089	95.4	95.3	94.5	0.89	0.87	0.82	6.60	1 150	2 750
400	355LB4	1 510	400	642	2 637	95.9	95.8	94.8	0.90	0.89	0.85	8.00	1 260	2 750
450	355LC4	1 508	400	731	2 965	96.1	96.0	95.3	0.89	0.87	0.86	10.3	1 450	2 750
550	355LD4	1 508	400	893	3 620	96.2	96.0	95.4	0.89	0.87	0.81	12.0	1 670	2 750
700	400LA4	1 507	400	1 137	4 573	96.9	96.9	96.4	0.89	0.85	0.70	12.2	2 333	2 750
800	400LB4	1 507	400	1 299	5 221	97.0	97.0	96.5	0.89	0.84	0.86	13.7	2 491	2 750
900	400LC4	1 506	400	1 445	5 871	97.1	97.0	96.5	0.90	0.88	0.83	15.7	2 691	2 750
1 100	450LA4	1 507	690	1 035	7 179	97.0	96.8	96.2	0.89	0.88	0.83	28.9	3 666	2 500
1 250	450LB4	1 507	690	1 164	8 149	97.1	97.0	96.4	0.90	0.89	0.85	33.3	3 889	2 500
1 400	450LC4	1 506	690	1 318	9 133	97.1	97.0	96.1	0.89	0.87	0.81	37.6	4 271	2 500
1 600	500LA4	1 505	690	1 541	10 445	97.1	96.8	96.0	0.87	0.85	0.80	53.0	5 353	2 500

1 800	500LB4	1 505	690	1 694	11 715	97.4	97.3	96.7	0.89	0.89	0.86	59.9	5 728	2 500
2 000	500LC4	1 505	690	1 926	13 030	97.3	97.0	96.3	0.87	0.86	0.81	68.8	6 003	2 500

6 Poles 1000 rpm 50 Hz

Power Pn KW	Type	Speed rpm	Voltage Vn V	Current In A	Torque Tn Nm	Efficiency (%) 4/4	3/ 4	2/4	Power factor 4/4	3/ 4	2/4	Inertia J Kg m²	Weight Kg	Max overspeed rpm
110	315MA6	1 010	400	187	1 115	93.3	93.5	93.0	0.85	0.85	0.81	2.90	750	2 550
132	315MB6	1 013	400	224	1 331	93.5	93.8	93.2	0.85	0.85	0.81	4.10	850	2 550
160	315MC6	1 013	400	272	1 609	93.7	94.0	93.4	0.85	0.84	0.80	5.10	920	2 550
225	355LA6	1 007	400	383	2 641	95.2	95.1	94.3	0.85	0.82	0.74	8.20	1 160	2 550
270	355LB6	1 007	400	459	2 681	95.5	95,4	94.6	0.85	0.82	0.74	10.6	1 340	2 550
315	355LC6	1 007	400	529	3 121	95.7	95.6	94.9	0.85	0.83	0.73	12.3	1 460	2 550
375	355LD6	1 006	400	638	3 719	95.7	95.5	94.8	0.86	0.82	0.82	13.7	1 800	2 550
540	400LA6	1 010	400	907	5 313	96.0	96.2	96.0	0.86	0.86	0.82	19.0	2 278	2 550
610	400LB6	1 010	400	1 025	5 989	96.2	96.4	96.1	0.87	0.86	0.81	21.6	2 421	2 550
670	400LC6	1 010	400	1 113	6 572	96.3	96.4	96.1	0.87	0.86	0.82	23.6	2 564	2 550
720	400LD6	1 009	400	1 196	7 062	96.4	96.5	96.2	0.86	0.86	0.80	25.6	2 732	2 550
800	450LA6	1 006	400	1 344	7 854	96,6	96.5	96.0	0.86	0.85	0.80	38.1	3 569	2 000
900	450LB6	1 006	400	1 512	8 826	96.7	96.6	96.1	0.86	0.85	0.80	43.5	3 843	2 000
1 000	450LC6	1 006	400	1 680	9 797	96.8	96.7	96.2	0.86	0.85	0.80	48.8	4 128	2 000
1 200	500LA6	1 005	690	1 169	11 743	97.0	96.8	96.3	0.87	0.85	0.80	66.2	5 039	1 800
1 400	500LB6	1 005	690	1 344	13 686	97.1	97.0	96.4	0.87	0.86	0.80	77.1	5 525	1 800
1 600	500LC6	1 005	690	1 541	15 642	97.1	97.0	96.5	0.89	0.86	0.80	88.9	6 015	1 800
2 000	550LA6	1 005	690	1 883	19 532	97.2	97.1	96.6	0.89	0.88	0.86	154.3	7 476	1 800
2 300	550LB6	1 004	690	2 165	22 461	97.3	97.2	96.6	0.89	0.88	0.86	178.7	8 271	1 800
2 700	550LC6	1 004	690	2 513	26 340	97.4	97.3	96.8	0.90	0.89	0.87	206.9	8 981	1 800

Class F standard insulation system allows a maximum winding temperature rise up to 105° C in reference to an ambient temperature of 40° C. Generators are equipped with three PTC thermistors (one for each phase) to supervise the winding temperature of the stator. In addition generators can be supplied with a temperature sensor PT100 for each bearing.

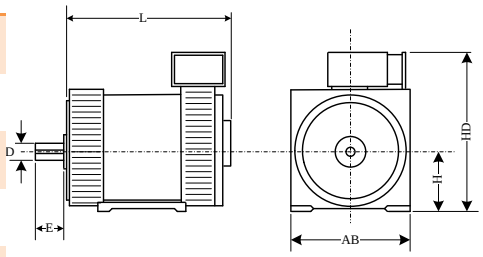
In case that the requested moment of inertia is higher than the standard value it is possible to extend the shaft in order to adjust a flywheel.

The main dimensions are given in the following tables for horizontal and vertical orientation.

Asynchronous generators-overall dimensions (mm)

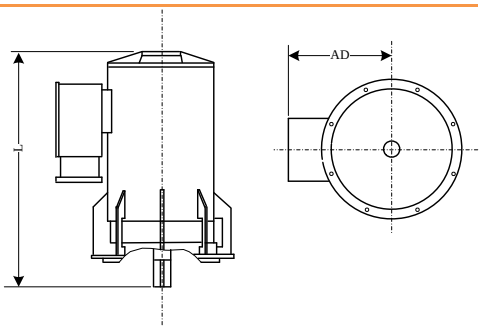
Air cooled (ICO1) – Horizontal mounting

Dimension (mm)	250	280	315	355	400	450	500	500
H	250	280	315	355	400	450	500	530
HD	573	701	388	1 000	1 206	1 320	1 402	1 656
AB	460	520	500	300	390	900	1 040	1 300
L	308	901	1 125	1 525	1 790	2 160	2 145	2 200
D	75	80	90	100	110	120	130	160
E	140	170	170	210	210	210	250	300



Air cooled (ICO1) – Vertical mounting

Dimension (mm)	250	280	315	355	400	450	500	500
P	560	560	800	800	1000	1 150	1 150	1 600
AD	358	369	550	585	750	835	830	1 080
L	323	421	1 115	1 590	1 840	2 300	2 095	2 500
D	75	80	90	100	110	120	130	160
E	140	170	170	210	210	210	250	300



2.10.2. Mechanical power transmission

a) Introduction.

The mechanical power N developed on the shaft of the turbine (toque M_T multiplied by the angular speed of rotation ω_T) must be transmitted to the shaft of the electrical generator that will convert the mechanical power to electrical. As explained in paragraph 5 the speed of rotation of the water wheel (of the order of n_T=9 to 20 for horizontal axis wheels and of the order of n_T=60-100 rpm for vertical axis wheels) is not suitable for direct coupling of the shaft of the water wheel with the electrical generator taking in consideration that for the range of power considered the most appropriate speed of rotation of the generator is 1,500 rpm. It is therefore necessary to use a transmission system with speed multiplication by a system of pulleys with belt or chain transmission or a gearbox.

According to the characteristics of the water wheels, the multiplication ratio is of the order of:

- $\nu=n_G/n_T=1500/15=100$ for horizontal axis water wheels and
- $\nu=n_G/n_T=1500/80=18.75$ for vertical axis water wheels.

b) Pulleys and belts.

Two types of pulley belt are commonly used in association with very small hydro schemes, the V-belt and the flat belt. V-belts are the most suitable for very small hydro plants, as they are smaller, lighter, easier to install and maintain and of lower cost compared with flat belts. A more modern version of the V-belts is the wedge belt that can transmit more power as they are deeper as shown in figure A_4, but they are more expensive than V-belts. V-belts and wedge belts of the same size (Z and SPZ for example) can both be used on the same pulley.

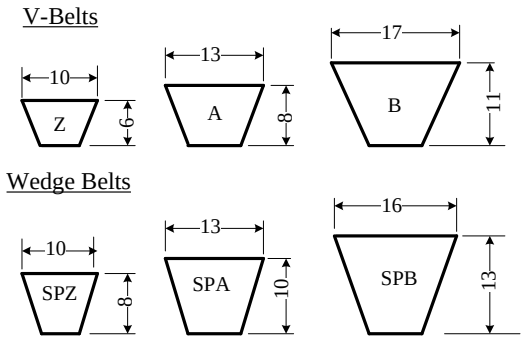


Figure A4: Cross section of V-belts and wedge belts of different sizes

Denoting by D_T the diameter of the pulley mounted on the turbine shaft and by D_G the diameter of the pulley mounted on the shaft of the generator, the speed ratio ν will be equal to the inverse ratio of the diameters (Fig. A_5) $\nu=\frac{n_G}{n_T}=\frac{D_T}{D_G}$

For a given speed ratio the ratio of the diameters is fixed. It is therefore of interest to keep the cost as lower as possible selecting the smaller possible diameter D_G of the pulley mounted on the shaft of the generator. The minimum diameter is related to the tension developed on the belt and therefore to the load on the bearings of the generator. In the following table the minimum pulley diameter is given in relation to rating power and speed of rotation (of the generator).

After the selection of the diameter D_G of the pulley mounted on the shaft of the generator, the diameter D_T of the pulley mounted on the shaft of the water wheel is resulted from the known speed ratio ν.

Minimum pulley diameter in relation to the power transmitted and the speed of rotation

Rating power (KW)	n_G=1500 rpm	n_G=1000 rpm
	D_G min (mm)	D_G min (mm)
0.5-0.75	71	71
0.75-1.5	71	71
1.5-3.0	71	71
3.0-5.5	90	85
4.0-7.5	112	95

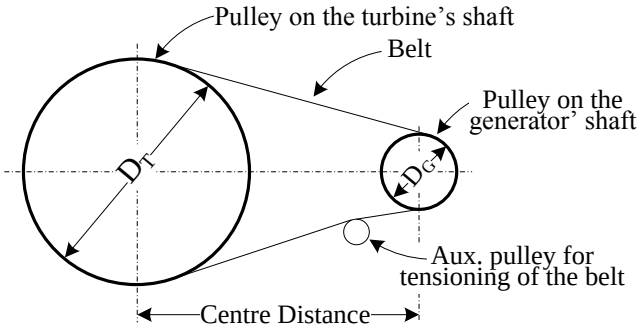


Figure A5: Arrangement of the pulleys

The power that can be transferred depends on the size of the belt (for example size Z, A or B for V-belt) and also on the size of the smallest pulley, as larger pulleys transmit more power because there is more contact area with the belt and less chance of slipping. The power that can be transmitted by one belt is given in the following tables for different size of pulleys.

Power per belt for V-belt and wedge belt drives

Belt size Z	Rated power (KW) per belt according to the pitch diameter of the pulley (mm)						
rpm	D=71 mm	D=80 mm	D=85 mm	D=90 mm	D=95 mm	D=100 mm	D=106 mm
1 000	0.70	0.80	0.90	1.00	1.10	1.20	1.30
1 500	0.90	1.10	1.30	1.40	1.50	1.70	1.80
3 000	1.50	1.90	2.10	2.30	2.50	2.80	3.00

Belt size A	Rated power (KW) per belt according to the pitch diameter of the pulley (mm)						
rpm	D=90 mm	D=100 mm	D=112 mm	D=125 mm	D=132 mm	D=140 mm	D=160 mm
1 000	1.10	1.40	1.80	2.10	2.30	2.60	2.90
1 500	1.50	1.90	2.40	2.90	3.20	3.50	3.90
3000	2.30	3.00	3.80	4.60	5.00	5.50	5.30

Belt size SPZ	Rated power (KW) per belt according to the pitch diameter of the pulley (mm)						
rpm	D=71 mm	D=75 mm	D=85 mm	D=95 mm	D=112 mm	D=125 mm	D=140 mm
1 000	0.80	0.90	1.20	1.40	1.90	2.20	1.70
1 500	1.10	1.30	1.60	2.00	2.70	3.20	3.70
3 000	1.80	2.10	2.80	3.50	4.70	5.50	6.40

Belt size SPA	Rated power (KW) per belt according to the pitch diameter of the pulley (mm)						
rpm	D=90 mm	D=100 mm	D=112 mm	D=125 mm	D=132 mm	D=140 mm	D=160 mm
1 000	1.40	1.80	2.30	2.90	3.20	3.50	4.10
1 500	1.90	2.50	3.20	4.00	4.50	5.00	5.50
3 000	2.90	4.00	4.70	6.70	7.40	8.20	8.50

Correct tensioning of belt drive is important for reliability and efficiency. Under-tensioning creates slippage that generates excessive heat and shortens the life of the belt. Over-tensioning also shortens belt life and also increases the load on all the bearing. The life of bearing also will be reduced under increased load. Some means of adjusting the centre of the two shaft is required (in the case under examination the electrical generator must have the possibility for adjustment) for installation of the belt and adjustment of the tension. The measurement of the tension can be achieved by the use of a simple spring balance.

c) Flat belts.

The advantages of flat belts is the simple construction, the low cost, the high flexibility, high tolerance to overload while as disadvantages the noisy operation, the low efficiency can be reported. In addition it is possible the sliding during the operation and that tensioning is required. In order to achieve optimum exploitation of the drive the belt must be assured n even run on the pulleys. This can be achieved by giving the pulley a smooth crowned face with a camber. The main advantage of the flat belt, compared to

the conical belts, is that it can be opened for the positioning by a system of clutches, and then reclosed.

The flat belt can be applied for fully turned transmission 180° as well as for semi turned transmission 90°.

The belt width is standardised for widths from 25 to 500 mm. The recommended maximum linear belt speed is 20 to 40 m/sec. The power that can be transmitted with flat belts depends on the speed of rotation and the diameter of the smaller pulley. For the speed of rotation of 1450 rpm the power P in KW that can be transmitted per 10 mm of belt width is given in the following table for versus the diameter D of the smaller pulley

Power rating in kW per 10 mm of belt width and for n=1450 rpm

D (mm)	80	125	200	315	400	630
P (kW)	0.56	1.34	2.45	3.68	4.16	4.49

d) Gearboxes.

d.1) Introduction.

The gear box is a mechanical device used to increase or reduce the speed of rotation on a rotating axis or to increase or reduce the torque. In the case of small hydro or wind turbine the gear box is used as a speed multiplier in order to adjust the speed of rotation between the shaft of the runner (water wheel or rotor) to that of the electric generator. The main components of one gear box are the gears (a wheel with teeth shaped around the peripheral, and fabricated by stainless steel) in almost all the industrial applications. Among the large diversity of gears a gearboxes in the following only the gearboxes appropriate for speed multipliers in hydro application are examined, and namely the planetary or the parallel axis gearboxes equipped with helical (Fig. A_{6a}) or spur gears (Fig. A_{6b}). As during the rotation of the gears the teeth are meshed one by one, the ratio of the speed of rotation is equal to the inverse ratio of the number of teeth.

In the case of parallel axis gearboxes in order to obtain high values of the transmission ratio multiple stages (pairs of gears) are placed in series. This arrangement increases the multiplication ratio but in the same time increases the overall dimensions. Unlike the parallel shaft gearboxes the planetary gearboxes in which the input and output axis are coaxial and as they are multiple power branches, the loads on the gears are reduced and consequently the planetary gearbox is smaller in dimensions and lighter compared to the corresponding parallel axis gearbox.

Figure A6a, A6b: a) Helical gears and b) Spur gears

The parallel axis spur gearboxes are mainly used for low power applications and they are characterised by the imposed dimensions, weight and relatively small transmission ratio. In comparison to the parallel axis gearbox, the planetary gearbox is more compact achieving higher transmission ratios with acceptable efficiency.

d.2) Dimensions of standardised planetary (coaxial shaft) gearboxes.

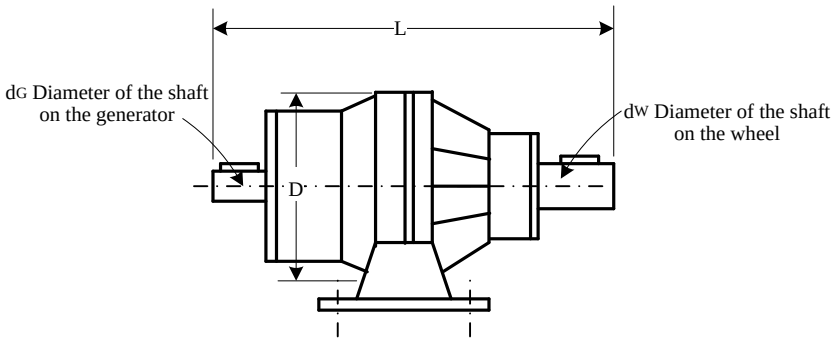
Some indicative characteristics and dimensions are given in the following taken from catalogues of standardised planetary gearboxes (coaxial axis) for the range of power and transmission ratios appropriate for coupling with water wheels. In all cases the speed of rotation of the generator is taken equal to 1,500.0 rpm

Transmission ratio ν=100 (appropriate for horizontal axis water wheels)

Size	Torque on the wheel (Nt m)	Nom. Power kW	d_G (mm) Shaft diameter on the generator	d_W (mm) Shaft diameter on the wheel	Length L (mm)	Housing diameter D (mm)
1	27 500	41.00	60	120	1 123	420
2	18 200	27.00	48	110	9 69	360
3	10 500	15.65	38	90	788	315
4	6 420	9.57	38	80	678	265
5	3 450	5.14	35	50	501	215

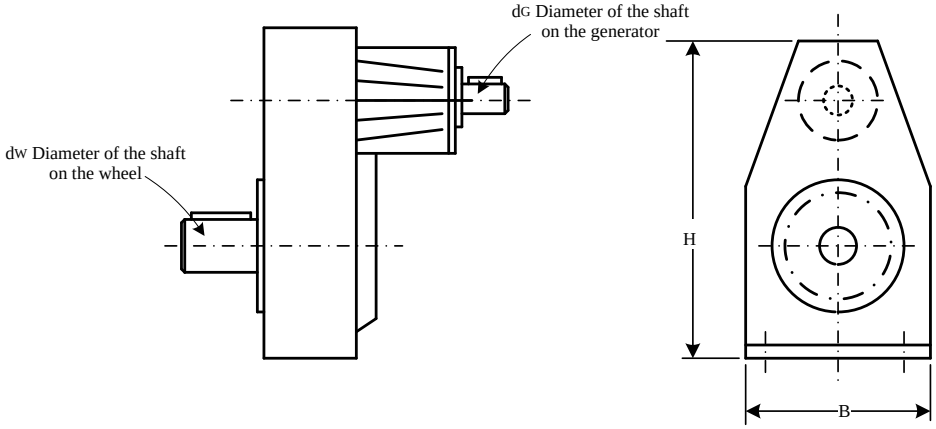
Transmission ratio ν=16 (appropriate for vertical axis water wheels)

Size	Torque on the wheel (Nt m)	Nom. Power kW	d_G (mm) Shaft diameter on the generator	d_W (mm) Shaft diameter on the wheel	Length L (mm)	Housing diameter D (mm)
1	22 000	20.80	60	120	940	420
2	14 000	1.23	48	110	813	360
3	8 530	8.06	38	90	700	315
4	4 940	4.67	38	80	587	265
5	2 710	2.56	35	50	455	215



d.3) Dimensions of standardised planetary (coaxial shaft) gearboxes.

Some indicative characteristics and dimensions are given in the following taken from catalogues of standardised parallel axis gearboxes for the range of power and transmission ratios appropriate for coupling with water wheels. In all cases the speed of rotation of the generator is taken equal to 1,500 rpm.



Nominal Power N=4 KW, Transmission ratio ν=16 : B=200 mm, H=350 mm

Nominal Power N=3 KW, Transmission ratio ν=100: B=300 mm, H=460 mm

d.4) Comparison of torque transmissions systems.

On the following table the main characteristics of different transmission system are given in order to facilitate the comparison and the selection of the proper system.

Characteristic	Spur gears	Flat belts	V-belts	Chains
Max Power (kW)	80 000	200	350	400
Max Torque (kNm)	7 000	3	5	40
Max linear speed (m/s)	20	100	30	10
Efficiency (-)	0.97	0.97	0.97	0.95
Max. ratio (one stage)	6-10	6-8	6-10	6-10

Tensioning required	no	yes	yes	no
Load on bearing	low	high	high	low
Build precision	high	low	low	average
Presence of sliding	no	yes	yes	no
Noise	average	low	low	high
Overload limiter	no	yes	yes	no
Cost	high	low	average	average

2.10.3. Archimedes screw generator

a) Introduction.

The main interest for Archimedes screw is that it is ideal for the replacement of waterwheels or other types of low head, low output turbines. It must also be noticed that the typical horizontal axis waterwheels are almost not any more fabricated and the only alternative solution for the replacement of an old water wheel is either with a small Cross-Flow turbine or an Archimedes screw generator.

Archimedes screw is a type of screw that has been known since antiquity where was used as a pump. It continues to be used as a pump for pumping water to a relatively low head at large flow rates for the case of water with solid load, as waste water, in water treatment plants. Recently (about 2005 and afterwards) it is also used in the reverse operation as water turbine, to generate electricity from natural flow streams (rivers) or to recover energy from industrial plants as cooling water outlet from thermal power stations, process water from paper of steel mills, water treatment outfalls at relatively low head.

b) Description and characteristics.

The Archimedes screw generator consists on a helical screw fixed on a drum rotating inside a cylindrical trough as shown in figure A7.

The optimum inclination of the screw axis is approximately 22^{o}. It was proven experimentally that the inclination of 25^{o} corresponds to the highest overall efficiency, of the order of 75%. The other characteristics influencing the operation are:

- The diameter D of the screw. If all other factors remain equal, as the diameter of the screw increases the flow rate and the generated power increase. An important parameter that needs more investigation is the ratio between inner and our diameters of the spiral.
- The speed of rotation. If all other factors remain equal, as the speed of rotation of the screw increases the flow rate and the generated power increase.

- The number of blades. If all other factors remain equal, a screw with more blades can handle a greater volume of water and therefore it can generate more power.
- The pitch. The pitch is the peripheral spacing between the blades of the screw and it is equal to the perimeter of the screw divided by the number of blades.

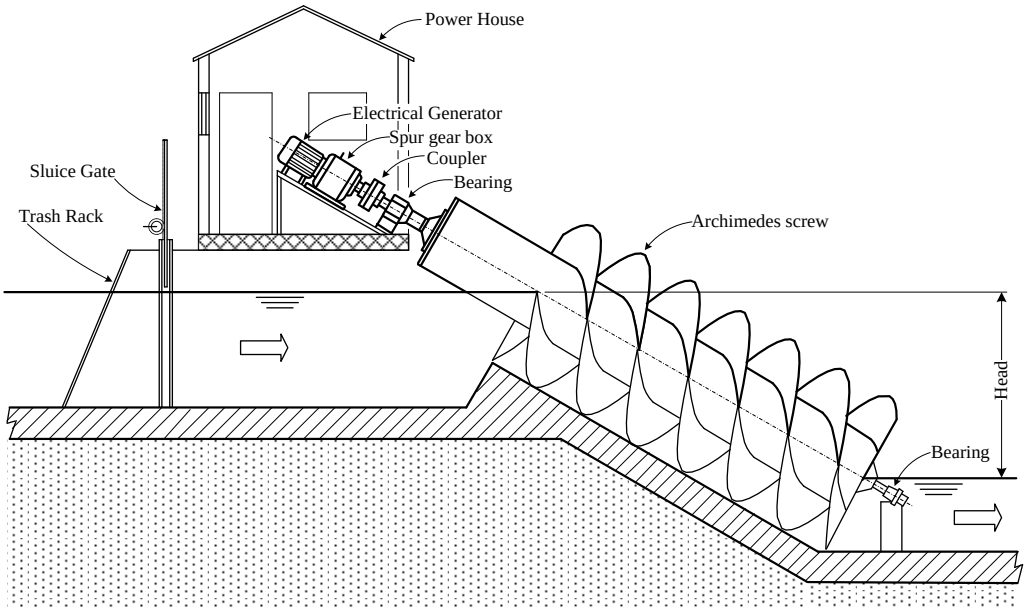


Figure A7: General lay-out of power plant equipped with Archimedes screw generator

Archimedes screws as water turbines are standardised and fabricated for the following range:

Flow rate: Q=0.1-10.0 m^3/sec

Head: H=1-7 m (in cases of higher head two-stage screws in cascade are also reported)

Power output: P=3(5)-500 kW

The overall efficiency is of the order of 75%

The operating range of Archimedes screw generator in comparison to other classical turbine configurations is given in figure A8.

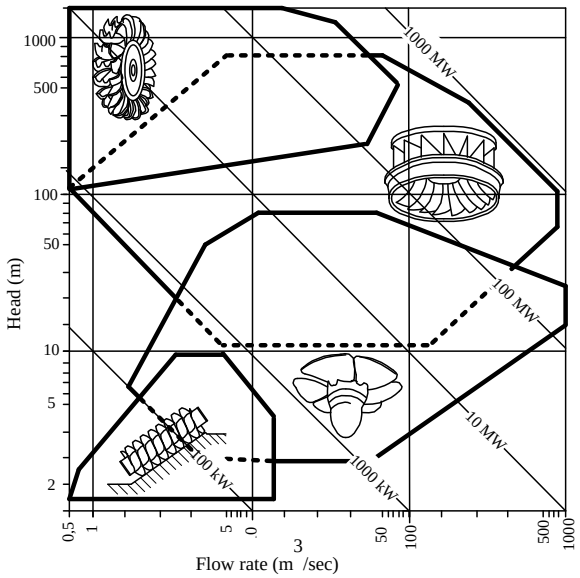


Figure A8: Diagram of the operating range of Archimedes screw generator in comparison to that of classical Kaplan (Axial-Flow), Francis and Pelton turbines

The main advantages of Archimedes screw as generator are:

- The high efficiency under a wide range of flow rate. In fact the curve of the efficiency versus the flow rate as well as versus the flow rate is flat as given on the diagram of figure A9, in comparison to Francis and Axial-Flow turbines.
- It is simple and reliable as the speed of revolution is very low, resulting low wear, and it is consisted of a few wear parts.
- Low maintenance due to the simple and robust design.
- It is fish friendly as the fish can run through the screw without damage due to the low velocity flows, low speed of rotation and the large space between the blades.
- No fine screen is necessary upstream and only a simple 100-120 mm screen is used to prevent large items enter the screw.
- Appropriate for wide range of flow rate as it is capable to handle flow rate from 0.1 to 15 m^3/sec.
- Relatively simple civil works and of relatively low cost are needed for the installation.
- No continuous control at the inlet of the water to the screw is needed and only an ON-OFF control will be provided performed by a gate located upstream. In case of very low level (very low flow rate) the gate will be closed.

This last characteristic is the main advantage of the Archimedes screw generator over the classical types of turbines (Cross-Flow, Turgo, Pelton, etc) as, into the operating limits of the generator, the incoming flow rate and the level at the inlet can vary without the need of any adjustment (as the needle position for the case of Turgo or Pelton turbine or the guide vane opening for the case of Francis or Axial-Flow turbine).

Archimedes screw as generator can be applied in cases of low or very low head where the classical selection leads to a Cross-Flow, Kaplan type turbine. The Archimedes screw

compared to an equivalent Axial-Flow turbine is by 20% cheaper and n addition it is fish friendly.

The main disadvantage of Archimedes screw generator is the prominent dimensions of the equipment is size. For a site with available head H=6.7 m and flow rate Q=0.272 m^3/sec the appropriate Archimedes screw produces about 13.5 kW rotating at 53 rpm. For inclination of the axis equal to 30° the diameter of the screw is D=1.0 m while the total length is of the order of 15 m.

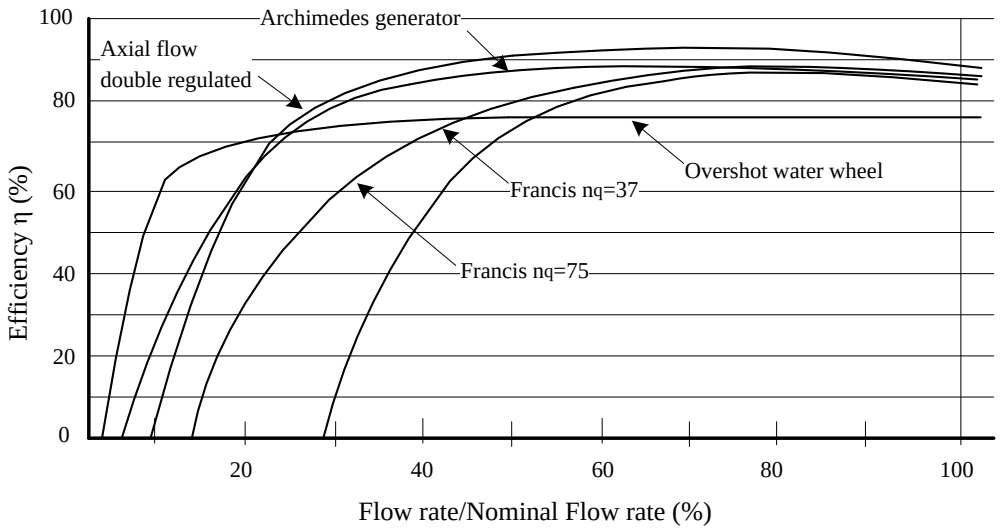


Figure A9: Efficiency of hydraulic turbines versus the load (ratio of the flow rate to the nominal flow rate)

The screw is rotating inside a cylindrical trough of diameter almost equal to that the screw. The radial gap between the screw and the trough is of the order of 3-5 mm. The trough is made of concrete or it can be prefabricated by steel sheets. By this last choice the civil costs are minimizes. The complete screw can also constructed as a single compact prefabricated unit in which it is possible to include the gate and the bar screen. In case that no civil works exists this last configuration saves civil work and installation costs.

The standard drive consists of a generator connected by a flexible coupling to the gearbox. The drive is designed to create minimum efficiency losses in the gears and couplings. A safety brake is applied to prevent over speeding when the grid is disconnected. The upper and lower bearings are designed to accommodate radial and axial loads. Normally they are oversized in order to assure a long life. The upper bearing is lubricated by an automatic grease lubricator, while the lower is usually a sealed for life bearing. As the sealed for life roller bearing is completely enclosed the leakage of lubricant into the river is prevented.

As the speed of rotation of the screw is very low a drive train is necessary for the transmission of the torque to the electrical generator with speed increase. The standard drive consists of a generator connected by a flexible coupling to the gearbox. A safety brake is also provided in order to prevent over speeding in case of grid disconnection.

An important part of the screw generator is the gate and its control. The gate gives the facility to control the flow over the weir and through screw generator. The weir gate will open and close under hydraulic pump pressure and will open and close under hydraulic pressure generated by a pump and also will shut quickly upon an urgent shutdown or power failure (failsafe operation). In this case the gate shuts down quickly, in a controlled manner and stops the generator.

2.10.4. Cross-Flow turbine

a) Description.

The Cross-Flow turbine, known also as Ossberger turbine by the name of the company that is making it for more than 60 years, is composed by two major parts, the runner and the nozzle. The runner has the form of a circular two dimensional rotor limited by two circular disks, normal to the shaft. The curved 2-dimensional blades are formed by metal sheet. They are fixed between the two disks, at their periphery. The nozzle directs the water flow to the periphery of the rotating runner at a certain angle of attack, producing mechanical energy, on the first stage of the runner. Afterwards the water leaves the runner crossing the runner to an almost opposite direction, producing energy to the second stage. By the rotation of the nozzle the flow passage and therefore the flow rate is adjusted to the desired value. The general configuration of a Cross-Flow turbine is given on figure A10a while on figure A10b an isometric view of a typical Cross-Flow turbine is shown.

The main advantages of the Cross-Flow turbine are its simple structure and the ease of manufacturing and maintenance on site of the plant. The disadvantages are the very large dimensions, especially compared to reaction turbine (Francis or Axial-Flow turbines), and that the maximum overall efficiency is of no more than 84%.

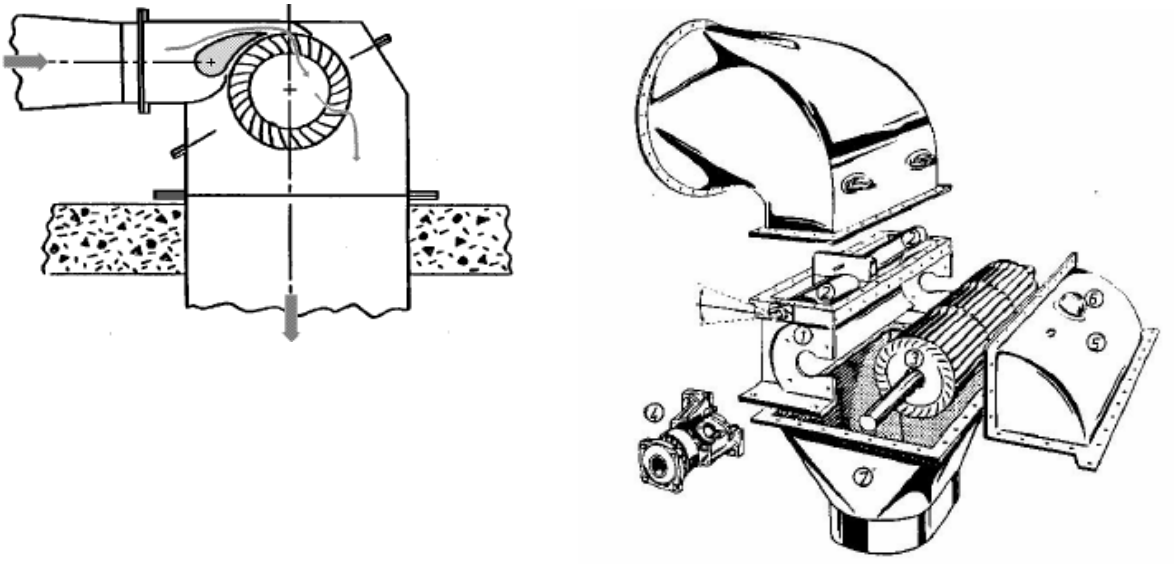


Figure A10a, A10b: a) Typical configuration of a Cross-Flow turbine and b) Isometric view of a Cross-Flow turbine

b) Operating characteristics.

The Cross-Flow turbine is ideal for medium to low head as shown on the diagram of figure A11 in comparison to the operating range of Turgo turbine and Archimedes screw generator. The curve of the efficiency versus the flow rate is flat, similar to that of Pelton turbines, but the maximum efficiency cannot be higher than 84%. The flow range can be extended if the nozzle and the runner are divided in sectors, as shown in figure A12.

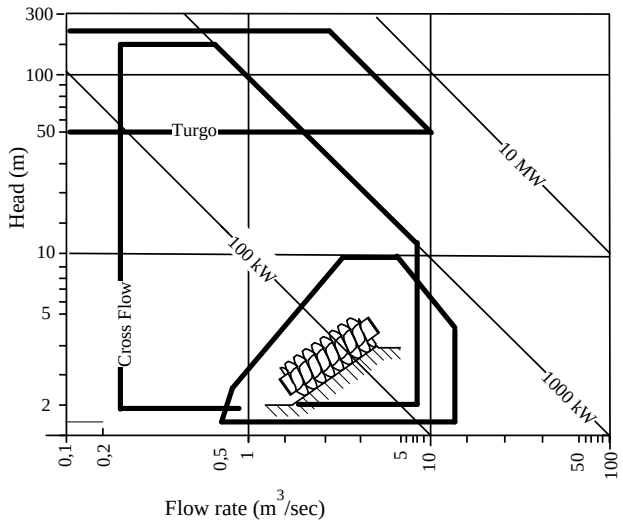


Figure A11: Operating range of Cross-Flow turbines compared to that of Turgo turbines and Archimedes screw generators

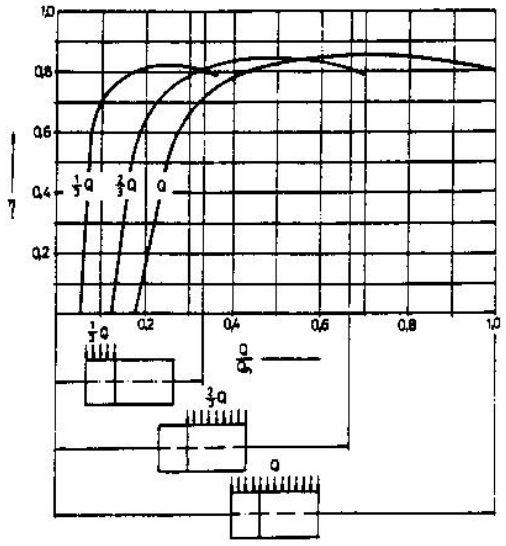
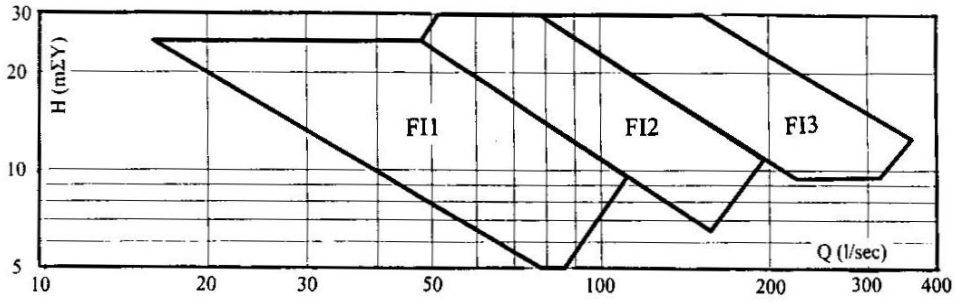


Figure A12: Efficiency of Cross-Flow turbine versus the flow rate

c) Standardisation and dimensions of Cross-Flow turbines.

Cross-Flow turbines are standardised by many companies; the more traditional among them is Ossberger which manufactures turbines of nominal power up to 1,000 kW. The company IREM is producing very small Cross-Flow turbines of nominal power 7.15 and 30

kW. On figure A13 the operating range as well the main dimensions of the standardised Cross-Flow turbines are given.



Type	N_{max} (KW)	A	B	C
FI 1	7	1 050	600	450
FI 2	15	1 400	800	600
FI 3	30	1 750	1 000	750

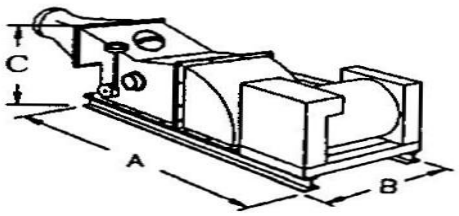


Figure A13: Operating range and main dimensions of standardised small Cross-Flow turbines

Chapter 3

Funding

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3. Funding

The purpose of this chapter is to provide information on access to funding for the refurbishment of small and micro hydropower sites in the eight RESTOR Hydro target regions, including Lithuania, Sweden, Slovenia, Belgium, Greece, Italy, France and Poland.

Different funding options with revenue generating potential, such as EU Structural Funds, redevelopment agencies, banks, private investors, cooperative public shares offering have been explored and the best mixture was suggested according to the needs and possibilities of each target region. The changed situation related to the 2014-2020 EU Cohesion Policy has been considered. For each of the target countries, a detailed list of all available funding options is provided.

3.1. Community shares based cooperative

In opposition to the model of receiving risk capital from shareholders who are expecting to maximise profit, the community shares based cooperative is following another approach. The cooperative members themselves are owners, investors and customers who can play an active role in the project. The return on investment will not be their major driver. In contrary to no transparent investment products the cooperative members are having the possibility to get involved in the project, albeit as a volunteer, as an expert, as an adviser or as a loyal customer.

An example for the set-up of a business model for a community shares based cooperative is provided under the following link:

www.restor-hydro.eu/documents/2013/04/cooperative-business-model.pdf.

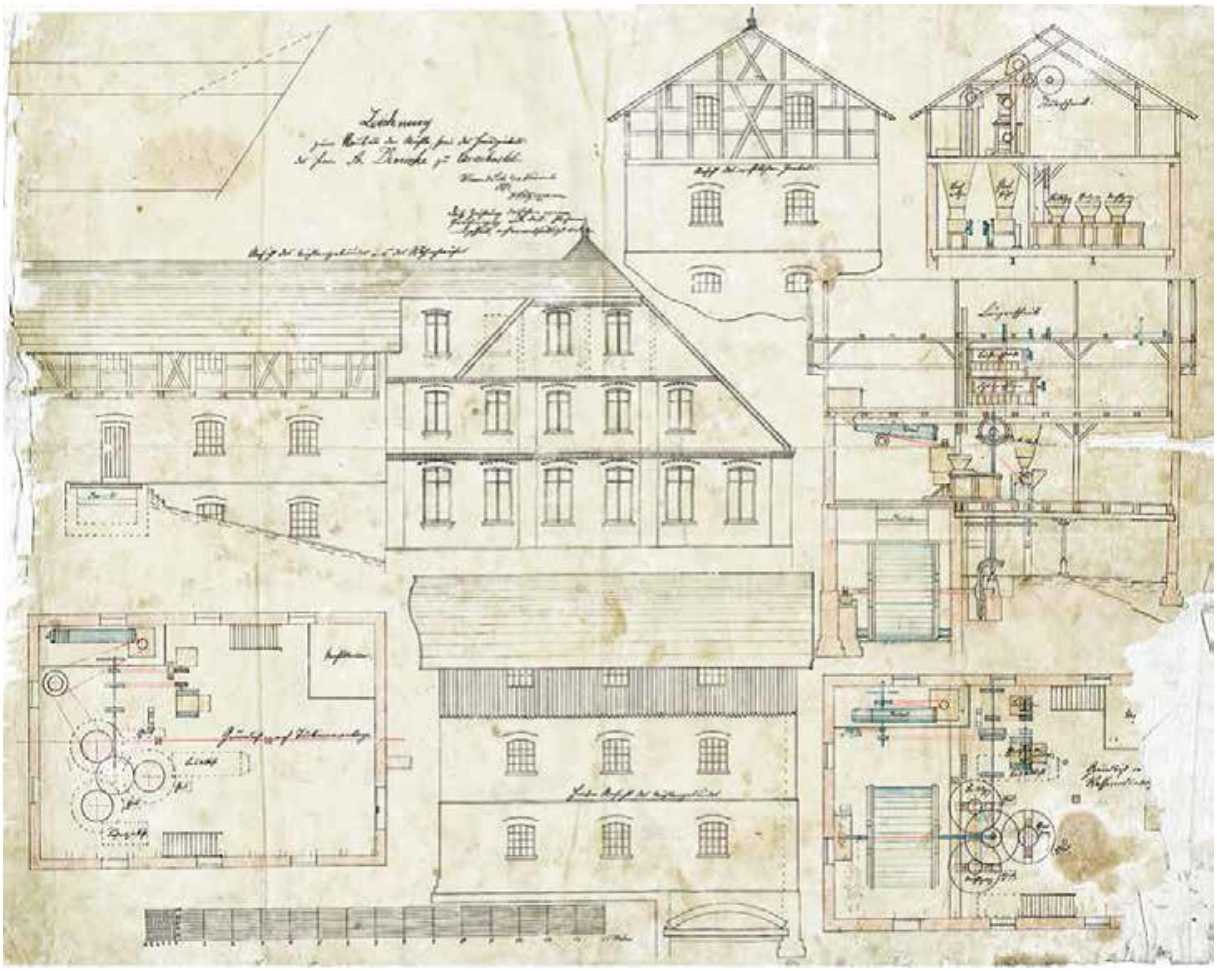
3.1.1. Financial model for the locally owned and governed cooperative

Given the fact that in the eight target countries different regulatory frameworks exist, one cannot provide a "one-size-fits-all" financial model. Notwithstanding within the RESTOR Hydro project a detailed financial tool has been developed which is free to be used by everyone interested in renovating or putting up a new small or micro hydropower plant. By replacing the general variables in the template by specific local variables one can get a good idea on the financial key indicators of the project. For further information please access the financial model here: www.restor-hydro.eu/documents/2012/10/d3-1-2.xlsx.

3.1.2. Good practice example of successful micro hydro cooperative

The watermill Wassermühle Karoxbostel in Seevetal-Karoxbostel south of Hamburg is an example of a successful micro hydro cooperative in Germany. The first documented mention of the watermill dates back to the year 1438 and is officially recognised as a historical monument. After the passing away of the last miller in 2011 the building was left empty and without any further use. The building started to decay and neighbours reported on theft of historical and antique objects. To avoid further damage and save the

historical mill, in the beginning of 2012 citizens from Seevetal and nearby joined together into a registered association. This form of organisation enables the members to apply for special grants (such as a special fund for mills in Germany). The project receives amongst others donations of the German Monument Protection (*Trust Deutsche Stiftung Denkmalschutz*) and of the Lower Saxony BINGO-Environment Trust (*Niedersächsische Bingo-Umweltstiftung*). Strictly speaking this project is not a cooperative, as the association does not aim to generate and distribute profits to their members; yet it serves as good examples of how to establish a similar project developed by citizens joining up in an interest group.



Historical plan of Wassermühle Karoxbeustel (Verein Wassermühle Karoxbostel e.V.)

The main objective of the association in restoring the old watermill very soon attracted a lot of citizens. Only two weeks after its foundation already more than 100 members signed up (current membership is 500 EUR; annual membership fee is 10 EUR). A website was set up to provide interested citizens the possibility to follow-up on the project progress (http://wassermühle-karoxbostel.de). Participating local craftsmen, who donated their working skills and material for the project in kind, received a web-banner on the website of the mill and are mentioned by name in the so called mill's diary, a web-blog about the activities in the mill. Cultural events, including music concerts and poetry readings are organised on the site of the mill, to generate additional income for the

project. In former times Wassermühle Karoxbostel was powered by one overshot wheel which provided enough energy to run a flour mill and a saw mill. Furthermore a generator for electricity production which was combined with accumulators was driven by the water wheel. The mill was supplied by several mill ponds which added up to altogether four hectares. The plan of the association is to restore the mentioned parts of the mill until the year 2017.

Wassermühle Karoxbeustel (Verein Wassermühle Karoxbostel e.V.)

3.1.3. Survey of the barriers for community shares based cooperative

The existence of the water management permit is crucial for a cooperative that plans to run or renovate a small hydropower plant. However, obtaining these permits can turn out to be a long lasting, complicated procedure. If the permit is not granted to the cooperative the whole project is at stake. Information about the Water Management Permit situation therefore has to be gathered in the very beginning of the project planning.

Hydropower is known to be a clean energy source with the possibility to reduce the CO_2 emissions of our energy mix. However, environmentalists are often in strong opposition against hydropower projects, fearing bad aftermath for flora and fauna in the water body. In some cases (deadlock situations) it is recommended to work with an enterprise which is specialised on mediation processes in the field of small hydropower.

Citizens and neighbours may also form opposition to such projects. Reasons may be envy ("I am not part of the business") or the typical NIMBY attitude ("not in my backyard"). The cooperative approach should facilitate getting these people on board of the project. High participation and awareness rising amongst citizens should be an integral part of the project activities.

Mobilisation of citizens to take a share in the cooperative may be difficult and not enough capital may be raised to fund the project. Reasons for the difficulty in mobilising citizens can be either lack of knowledge concerning the cooperative model or lack of trust in citizen-driven initiatives. In that case, the project implementation cannot be guaranteed. Enough resources should be dedicated for awareness rising and targeted marketing of the project amongst citizens.

Banks are probably the biggest barrier to a hydropower project, as it is becoming more and more difficult to obtain bank loans. Their "yes or no" can decide the success of a project. For that reason a good financial plan and a project feasibility study are obligatory when the cooperative is meeting for the first time with the representatives of the banks for credit negotiations.

Another barrier when trying to restore an old hydropower plant might be the application of the European Water Framework Directive (EWFD)[2]. The EWFD aims to achieve good qualitative and quantitative chemical, biological and ecological status for all water bodies by 2015 (in some cases by 2021). A typical consequence of the directive is the compulsory erection of a fish pass, which can lead to higher project costs than expected. It is absolutely important to get familiar with the implementation of the EWFD into national laws already at the initial stage of the project.

3.1.4. Recommendations for successful set-up of cooperatives

Three key recommendations for the successful set-up of cooperatives relating to participation, legal security and financing are summarised in this chapter.

a) Participation.

In order to raise interest and support for the SHP project among the local community at the very beginning of the project, steps should be taken to involve as many citizens as possible. The organisation of an information session can hereby function as a door opener towards sceptical locals. Showing the historical and cultural importance of an old site may also raise awareness in the community and ensure support from the competent authority.

b) Legal security.

As already mentioned in chapter 0 obtaining the water management permit is one of the most important legal aspects for a cooperative that intends to carry out a SHP project. Other permissions like construction permits become relevant in further stages of the project. In order to not to run into legal trouble during the set-up of the cooperative it is recommended to discuss and make a case by case agreement between the cooperative and the site owner. A formal Letter of Intent (LoI) must be signed before investments in a detailed preliminary study are done. This is to secure the involvement of the site owner. If the result of the preliminary study is positive, this agreement, with the help of a jurist, shall be formalised into a contract.

c) Financing.

[2] Link to Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000; multi-lingual and country specific versions available:
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060

Cooperative members will only be convinced to join if the investment shares covered by bank loans can be secured. When applying for a loan for a small or micro hydro project there is some information which is typically required by the banks[3], namely:

- a resource assessment;
- a project feasibility study (technical and economic evaluation) by a credible consultant;
- proven expertise in managing the type of project to be financed or an agreement with a qualified third party project manager;
- zoning and site permitting approval, including environmental impact studies;
- equipment performance data;
- equipment warranties and an operations and maintenance agreement;
- a completed interconnection study;
- a long-term power purchase agreement with a creditworthy utility that will purchase the electricity at specified prices;
- a business, financial and risk management plan for the project including complete pro-forma financial statements; and
- commitments for all required equity.

3.2. European Structural and Investment Funds (ESI)

European Structural and Investment Funds (ESI) formerly called Structural and Cohesion Funds (SCF) support the EU Cohesion Policy (CP) agenda over the period 2014-2020.

In the new funding period 2014–2020 the reformed cohesion policy will make available up to 351.8 billion EUR to invest in regions of Europe, cities and the real economy. It will be the principle investment tool for delivering the Europe 2020 goals: creating growth and jobs, tackling climate change and energy dependence, and reducing poverty and social exclusion.

This will be helped through targeting the European Regional Development Fund (ERDF) at key priorities such as support for small and medium-sized enterprises where the objective is to double support from 70 to 140 billion EUR over the seven years. There will be stronger result-orientation and a new performance reserve in all European Structural and Investment Funds that incentivises good projects. Finally, efficiency in cohesion policy, rural development and the fisheries fund will also be linked to economic governance to encourage compliance of Member States with the recommendations of the EU under the European Semester[4].

[3] Report on financial barriers and existing solutions, p. 18, pdf available: http://rescoop.eu/sites/default/files/project-resources/report_on_financial_barriers_and_existing_solutions_final.pdf

[4] http://ec.europa.eu/regional_policy/what/future/index_en.cfm

A common framework for the EU Cohesion Policy (CP) instruments, formerly known as EU Structural and Cohesion (SCF), has been developed in the new funding period 2014-2020. It includes the following three main instruments:

- European Regional Development Fund (ERDF).
- Cohesion Fund (CF).
- European Social Fund (ESF).

The European Regional Development Fund (ERDF)[5] aims to strengthen economic and social cohesion in the European Union by correcting imbalances between its regions. The ERDF focuses its investments on several key priority areas. This is known as thematic concentration' including:

- innovation and research;
- the digital agenda;
- support for small and medium-sized enterprises (SMEs); and
- the low-carbon economy.

Small and micro hydro projects in most cases will fall under the low-carbon economy theme.

The European Social Fund (ESF)[6] is main instrument for supporting jobs in Europe, helping people get better jobs and ensuring fairer job opportunities for all EU citizens. It works by investing in human capital in EU, its workers, its young people and all those seeking a job. ESF financing of 10 billion EUR a year is improving job prospects for millions of Europeans, in particular those who find it difficult to get work.

At time of finalisation of this publication, no official and approved information regarding Cohesion Funds for the new period has been available.

3.2.1. How do ESI work in the new programming period

At EU level, ESI are centrally managed by the European Commission (DG Regio). The EC negotiates and approves the National Strategic Reference Framework (NSFR) proposed by the Member States, and allocated resources.

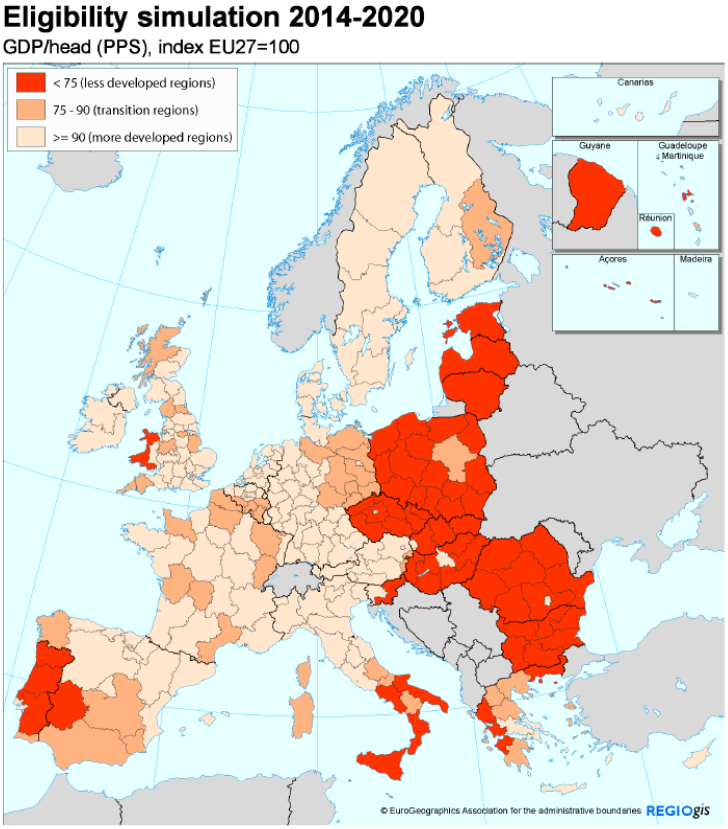
Each member state prepares Operational Programmes (OPs) that specify in detail the priorities and available budget for which the SCF can be spent on. Each OP is managed by a so-called Managing Authority (MA), which are always public entities.

The Management Authorities and contact information for all eligible countries can be found here: http://ec.europa.eu/regional_policy/manage/authority/authority_en.cfm

Every European region may benefit from the support of ERDF and ESF. However, a distinction between less developed, transition and more developed regions (see figure

[5] http://ec.europa.eu/regional_policy/thefunds/regional/index_en.cfm
[6] http://ec.europa.eu/esf/main.jsp?catId=35&langId=en

on next page) will exist in order to ensure concentration of the funds according to the level of Gross Domestic Product (GDP).



Eligibility simulation 2014–2020, according to GDP/head[7]

3.2.2. Combining ESI with the Horizon 2020 Funding Programme

From the new EU programming period 2014-2020 onwards, it is possible to combine the Horizon 2020 funding programme and the Cohesion Policy Funds (CP funds). Both funding instruments have shared objectives linked to the smart growth objective of Europe 2020.

The regulatory proposals by the EC set out the following main elements for facilitating linkages and concerted efforts between CP funds and Horizon 2020:

- The two actions share the same programming period of seven years that makes easier synchronisation of funding and provides for better planning with strong potential for real synergies.
- Although the two actions have distinct objectives, they share the same strategic goals of serving the Europe 2020 strategy for smart, sustainable and inclusive growth.
- Harmonisation of cost eligibility rules between Horizon 2020 and CP (lump sums, flat rates and unit costs possible under both for funding direct and indirect costs without providing documents proving real expenses, harmonisation of VAT rules)

[7]http://ec.europa.eu/regional_policy/sources/docoffic/official/regulation/pdf/2014/proposals/regulation2014_leaflet_en.pdf (page 16)

are major simplification for beneficiaries compared to the current multiple sets of rules.

- Possibility to combine CP and Horizon 2020 funding (and from other Union instruments) in same project for different expenditure items, which opens the way to combined funding of individual Horizon 2020 projects (Art. 55(8) of proposed Gen.Reg.[8]).
- Possibility to invest in other EU regions from a mainstream Operational Programme (OP), i.e. up to 10% of an OP budget (for EAFRD 3%) if the measure is for the benefit of the OP territory, which could be important for cross-border research infrastructure (incl. ESFRI Roadmap[9]) or cluster or value chain networking investments (Art. 60-2).
- The development of research and innovation strategies (RIS3) for smart specialisation is a conditionality for the approval of the R&I elements of the Partnership Contracts and the Operational Programmes. They are the key instrument to maximise also the synergies with Horizon 2020.
- The enhanced territorial cooperation CP budget share (3.1% of total ERDF of which almost 6% for inter-regional cooperation) that allows to build trans-national linkages between regional innovation actors, building on FP7 Regions of Knowledge and Research Potential measures or CIP cluster cooperation or networking of procurers or innovation agencies, but allowing to include less advanced regions in a targeted manner.

The strategic and operational coordination of the implementation of synergies between Horizon 2020 and CP funds is based on joint meetings between authorities and agencies involved in the implementation of CP and Horizon 2020 (including National Contact Points).

3.2.3. ESI and small hydro energy projects

Despite the apparent benefits of sustainable energy for regions and cities, so far only few renewable energy and small hydro energy related projects have been financed through Structural & Cohesion Funds. On average, in the funding period 2007–2013, New Member States have allocated 2.4% of their SCF budget to sustainable energy. This share represents an absolute amount of 4.3 billion EUR.

In the period 2014–2020, the Cohesion Policy will go further and a minimum share of each region ERDF allocation will be invested in measures supporting the shift to a low-carbon economy, including themes such as renewable energy, energy efficiency and clean urban transport.

A minimum share of the ERDF allocation each region will be invested in measures supporting the shift to a low-carbon economy:

- 20% in more developed regions;

[8] COM(2011) 615 final
[9] The European Strategy Forum on Research Infrastructures- roadmap

- 15% in transition regions; and
- 12% in less-developed regions.

This will ensure a minimum investment of at least 23 billion EUR for 2014-2020 from the ERDF, while further investments through the Cohesion Fund will further support the shift towards a low-carbon economy.

In the area of "increasing the use of renewable energy", investments from the ERDF and the Cohesion Fund will include:

- Investing in the production and distribution of energy derived from renewable sources.
- Supporting projects to build awareness and increase the use of renewable energy in both the public and private sectors.

It is not possible to find out about the share of budgets that will be allocated for small hydro energy projects, as Member States have the mandate to define their own funding priorities with the areas and the sub-areas. In most cases, Member States are still negotiating the agreements on national funding priorities. In any case, the share of budgets for renewable energy funded projects shall be considerably higher in the on-going funding period 2014–2020.

3.2.4. Previous small hydro power projects supported by structural funds

In the following, a few examples of successfully implemented small and micro hydro projects co-funded through SCF are presented[10].

a) Hungary.

In 2004-2006, the Hungarian Ministry approved one small hydro-power project co-financed with SF:

- Project: Small Hydro Power Plant on the Raba.
- Beneficiary: Hydro Power Consulting Hungary ltd.
- Place: Kenyeri (Vas, West Hungary).
- EU contribution: ~1.2 million EUR.

b) Slovakia.

Small hydro power plants have a long tradition in Slovakia. Due to the good geographical conditions there are dozens hundreds of such facilities operation. Many of them running more than 60 years now. In 2005, the Slovak Ministry of Economy approved five small hydro power oriented projects for funding from SF:

- Project title: Small Hydro Power Plant Svrckova.
- Beneficiary: Anna Chorvátová ALFA , district of Zilina.
- Allocated grant: 4.19 million SKK (1 EUR = 37.5 SKK)

[10] http://www.inforse.org/europe/Structuralfunds/SF_Hydro.htm#sf_hungary_hydro

3.2.5. Recommendations for successful acquisition of ESI

a) Information sources.

Finding and understanding the relevant information on how to apply for ESI funding shall not state any serious problem. Various channels of Ministries, Managing Authorities or networks exist, providing information on open calls, funding criteria, forms and procedures, and deadlines. Throughout the Union, internet based information on SCF application procedures is available in national languages. Information events are also very common and available. Furthermore, help desks or newsletters of specific multipliers (associations) as well as consulting companies provide information on SCF funding for their respective focus groups.

b) Documents needed.

In addition to the filled in application form and the co-financing guarantee, most of the construction-related projects require an audit in the course of the application project. Further materials sometimes include investment or development plans, in case of communal projects at times a formal council decision. Most projects need between two and four months, but some project preparations can take considerably longer, (i.e. when feasibility studies have to be submitted). The involvement of consulting companies often allows to speed up the process, but results in additional costs of often more than 10,000 EUR, which are not always eligible as project related costs in the project budget.

c) Co-Financing.

Even in situations with a high EU funding rate, the acquisition of the necessary co-financing can state a serious barrier to some project owners, i.e. non-profit organisations. Therefore, it is of great importance to address these financial issues at a very early phase in the project planning, since providing a co-financing guarantee is a must in the project submission. As a possible remedy to this situation, public bodies in some member states provide additional financial support from either the communal or the national level to make possible projects for institutions with limited capital stock or credit line at the bank.

d) Who can help you?

Managing Authorities (MA) administer SCF and can provide more information regarding your eligibility. If you need assistance in preparing your application, there are a number of private or/and state consultancies providing these services.

An overview of MAs in all 27 EU member states can be found at the following website of the European Commission:
http://ec.europa.eu/regional_policy/manage/authority/authority_en.cfm

3.3. Grants and regional loans

Whilst for all EU member states the EWFD is mandatory, grants and loans are distinct from country to country. For SMEs regional loans in some cases can secure the realisation of a project as they may be grants even without any interest (depending on

specific conditions). The following examples of the eight target markets show possible ways of how to achieve financial support through grants and regional loans (if available) for a small or micro hydro project.

3.4. Funding options in Belgium

In this section, the funding options in Belgium are shortly described. Given the size of the power plants that can be refurbished/ built in Belgium, most of the hydro energy projects are carried on by individuals or SMEs (including cooperatives). Some municipalities (following the Covenant of Mayors trend) start to be interested in refurbishing the existing sites on their territory, through own funds or communal rural development programs supported by the Regions.

The funding mostly comes from the private sector (equity or commercial loans) from individuals or public money in case a municipality is investing in the refurbishment.

Public support actions to installation or refurbishment of hydropower plants include investment aid from the Regions and tax deduction from the Federal State for investments in energy saving installations (both for enterprises only). An aid if the site has a particular heritage value is also available: for listed buildings and in Wallonia for the restoration of a water wheel that has public access.

Once the installation is running and producing electricity, an aid for energy production is available through a system of Green Certificates. In Flanders, hydropower is eligible to get green certificates, but the procedure has not been defined since the last change the authorities brought to the system. For the moment, each project has to apply separately for the supporting mechanism. If the installation is not eligible for green certificates the owner can apply like in Wallonia for an investment aid dedicated to environmental improvement[11].

3.4.1. Examples of RES/micro hydro cooperative projects in Belgium

The turbine Mill Van Doren in Rotselaar, listed building since 1983, is producing electricity since 1995 (75 kW installed capacity for an annual production of 500 MWh). This project was the cradle of Ecopower, a now major cooperative producing and distributing green electricity in Flanders, for more than 40.000 members.

Ecopower also owns a smaller hydropower plant Bovenslagrad IJse in Overijse (12 kW installed capacity for an annual production of 10 MWh) and the Watermill of Schoonhoven in Aarschot (10 kW installed capacity for 20 MWh annual production).

The Walloon cooperative Energie 2030 took part, in 1999, along with the municipality of Rochefort and private partners, in the foundation of the Hydroval company to build and exploit a hydropower plant in Poix-Saint-Hubert (178 kW for an annual production of 900 MWh).

[11] More info: http://www.agentschapondernemen.be/artikel/welke-investeringen-komen-aanmerking-incl-limitatieve-technologie%C3%ABnlijst

Despite the relatively high number of hydropower plants in activity in Belgium (116 beginning 2014), micro hydro cooperatives are not very common, perhaps because the remaining sites to refurbish (typically old mills or industrial sites) are most of the time strongly linked to private property.

12 kW SHP Bovenslagrad IJse in Overijse (Credits: Patrick Wheeler)

75 kW Molen Van Doren, Rotselaar (Credits: Dirk Vansintjan, Ecopower)

3.4.2. ESI Funds for micro hydro in Belgium

To our knowledge, no micro hydro projects have been financed through the European Structural Cohesion Funds in Belgium so far.

3.4.3. Grants and regionals loans in Belgium

Walloon (public) investment funds like the Regional Society for Investment in Wallonia (*Société Régionale d'Investissement de Wallonie*, SRIW) or SOCOFE or even groups of municipalities (so called *intercommunales*) participate in RE projects such as wind energy.

However, it is not the case for micro hydro power projects, because of the small amounts of money at play. Grouped funding (pooling) of several projects (up to 1 million EUR) with the participation of such partners for about 10% of the capital could however technically be envisaged.

When rural municipalities are involved in projects, they can have access to communal rural development programs financed by the Walloon Region. Currently they are a few municipalities that have submitted projects for the installation of micro hydro power for instance Houyet, Marchin and Vielsalm. The fund can finance from 65% to 80% of the costs, the remaining capital can be financed through commercial banks. Third party investors (see below) or even cooperatives can also join the municipality in the capital.

In the project of Val-Notre-Dame in Wanze (55 kW of installed capacity for an annual production of 150 MWh), one partner had the support of the European Agricultural Fund for Rural Development (through the LEADER program) to make the installation secure and produce didactic material.

A tax deduction for investments in energy saving installations is available for enterprises at the federal level.

In Wallonia, an investment aid for the environmental and sustainable use of energy is available for enterprises only. The level of the investment aid varies with the size of the company, its location and the objective of the investment. It is of 20% for SMEs; up to 100 kW, the ceiling of the amount of investment considered is 9,000 EUR/kW.

A Walloon regional aid for the refurbishment of wheels with public access is available (up to 7,500 EUR from the *Petit Patrimoine Populaire Wallon*) if the site has a particular heritage value12.

By refurbishing listed buildings with public access, one can benefit from a fiscal deduction up to 36,600 EUR (VAT included, amount not covered by subsidies)[13].

In Flanders, more than 200 of the remaining 320 watermills are listed as national monuments. As a result, up to 80% of the restoration costs are subsidised by the Flemish Region. The rest of the investment has to be financed on the basis of the income from the sale of electricity, green certificates and guarantees of origin.

3.4.4. Commercial loans and financing in Belgium

The private sector is offering loans specifically tailored for RE systems, having similar characteristics with a wide range of applications, size and technologies (energy saving, insulation, wind energy, solar water heating, photovoltaic plants, etc.) and targeting households, industry or SMEs. Both financing limits and terms vary according to specific projects and to case by case specific business plans (project finance).

[12] More info: http://dgo4.spw.wallonie.be/dgatlp/dgatlp/Pages/Patrimoine/Pages/Actualites/PPPW.asp
[13] More info :
http://dgo4.spw.wallonie.be/dgatlp/dgatlp/Pages/Patrimoine/Pages/Directions/ProtectionDeductibilite.asp

One private bank in Belgium, Triodos, is typically specialised in RE projects. Through the years, Triodos has financed at least five different micro hydro projects.

Recently, a project in Virelles (7 kW, a pilot installation of a new technology in Wallonia) was financed through a donation by the historical electricity operator/distributor Electrabel.

To some extent and especially for cooperatives, funds could be obtained through agencies for Social Economy like Crédal or Syneco in Wallonia.

Crowdfunding of creative and innovative projects (through platforms such as KissKiss BankBank) are more and more popular and this financing mechanism will be tested in the frame of the RESTOR Hydro project.

3.5. Funding options in France

In France, small hydropower plants (<12 MW) are eligible for feed-in tariffs, which may be considered a form of aid. The guarantee of origin and green certificate belong to the purchaser who is bound by the feed-in tariffs (EDF OA, in most cases).

As of early 2014, a reform is underway to develop funding support mainly orientated towards the electricity market. This situation is of concern to professionals as it would seriously affect the development of new power plants that need visibility and guarantees to acquire funding.

Other than feed-in tariffs, some small producers (approximately 450 MW) sell their production on the electricity market, in which case they can optimise their guarantee of origin.

With regard to grants and subsidies, a distinction must be made between the building of new power plants and the renovation of existing sites.

a) Building new small hydropower plants.

Public funds are very rarely granted. In general, financing is provided by bank loans. There are different types of loans. Project owners must provide many complex guarantees. To finance a new project, in general is required:

- a minimum of 20% to 30% of equity capital;
- pledge of a feed-in tariff contract;
- cash flow for at least two financial quarters;
- DSCR (debt service coverage ratio) of approximately 1.10/1.25; and
- a bank loan for a period ranging on average between 15 and 20 years, often divided into a number of loans from different banks.

b) Equipping existing weirs and restoring existing sites.

The situation varies and the producer must contact various funding sources:

- Water agencies offer subsidies to comply with environmental legislation, within the framework of restoration of ecological continuity (between 30% and 60% of the projects).
- Some Regional Councils *(Conseils Régionaux)* and General Councils *(Conseils Généraux)* have renewable energy subsidy schemes.
- The regional delegations of ADEME may also participate in the funding. For example, in Burgundy, the policy from ADEME is as follows:
    - Feasibility study: between 50% and 70% of the pre-tax amount of the study (50% for an industrial group and 70% for a small company or individual).
    - Investment: between 45% and 65% of the eligible hydropower base (cost of the hydropower plant based on 1,000 EUR/kW) and 20% for the fish ladder.
    - The ADEME imposes the following conditions:
        - Feasibility studies. A technical and financial feasibility study, according to standard specifications (on the Regional directorate website of ADEME for Burgundy: rhttp://www.bourgogne.ademe.fr/), must be systematically produced. This study must take into account the financing and execution of the works necessary for the management of the installation to ensures fish migration and sediment transport along the watercourse.
        - Investment. The installations must be environmentally exemplary with:
            - no bypass sections created;
            - equipped with fish-friendly turbines or other devices that allow reduced fish mortality during downstream migration (screen, etc.);
            - equipped with an upstream migration system (fish ladder, branch rivers, etc.) approved by ONEMA if requested by the DDT; and
            - the existence of functioning sluice gates or other devices that allow sediment transport.
    - In the event of subsidies for a fish ladder included within a global project, the payment of the balance of the grant will be withheld until the fish ladder has been implemented.
- The *Banque Publique d'investissement* (BPI), which has joined OSEO, may also be involved in the proceedings.

This funding may vary significantly from one region to another.

c) Practical example of an existing project

The implementation of the GAEC at Pré Couvent (21110 Tart-L'Abbaye) costs 232,888 EUR:

- The General Council (*Conseil Géneral*) financed 20%, i.e. 46,578 EUR.
- The Regional Council (*Conseil Régional*) financed 40%, i.e. 93,150 EUR.

- The producer self-financed 93,160 EUR.

3.5.1. Examples of RES/micro hydro cooperative projects in France

In France, there are very few RES cooperatives and micro hydro cooperative projects remain to be developed. There is however a cooperative which buys and sells renewable energies:

a) ENERCOOP is a public interest cooperative society.

A multi-stakeholder cooperative uniting members with different concerns (producers, consumers, associations, local authorities and SCIC employees) with a democratic, transparent structure subject to the *1 person = 1 vote* rule.

More than half (57.5%) of the profits must be reinvested with a view to achieving the objectives of the company and its consolidation, due to members placing public interests before individual ones.

The capping of potential profits agreed at the annual general meeting, gives a non-speculative and even a non-profit-making character to the cooperative.

b) The benefits of a local cooperative.

The cooperative statutes (SCIC) allow local authorities to be strongly involved (best political lever for locally elected officials) by means of a share of the capital on the decision of the Board of Directors. A regional structure also allows closer association with consumers, members, and partners; and is orientated towards the relocation of energy management. Finally, local cooperatives are obviously more suitable for the development of power production and energy service projects than a national structure. More information at: http://www.enercoop.fr/.

Energie Partagée is a movement which supports finances and federates citizen projects aiming to produce renewable energies: http://www.energie-partagee.org/ .

3.5.2. ESI Funds for micro hydro in France

Occasionally, the European Investment Bank (EIB) contributes to funding through agreements with the Regional Council, but these agreements are rare.

a) Example of an agreement between the Region and the EIB.

In the Midi Pyrenees region, a subsidised loan system that is unique in Europe for the production of renewable energies and the energy mix upgrade was launched. Companies, associations, local authorities and farms in the Midi-Pyrénées region may take advantage of 700 million EUR in subsidised loans for renewable energy. The EIB allocated 350 million EUR in funding, which was matched by regional partner banks, Crédit Agricole, Banque Populaire and Caisse d'Epargne (BCPE Group) with an additional 350 million EUR.

b) FEDER Fund.

In southern Corsica, a small company built a mini-hydropower plant on the Taravo River, with support from FEDER. The plant produces clean and safe renewable energy providing significant security to the electrical grid. This project includes the installation of a fish ladder and a canoe bypass. Fish migration is thereby significantly improved, and canoes can safely pass the facility. The project cost was 989,614 EUR, of which 141,932 EUR wer funded by FEDER.

Note that certain regional strands of the 2014-2020 FEDER funding program exclude the funding of renewable energy projects benefiting from a feed-in tariff (such as in Auvergne).

3.5.3. Grants and regionals loans in France

There is no regional coherent and homogeneous proactive policy aiming to develop small hydropower plants. The producer must contact various funding sources. For example:

- ADEME, Regional Council and FEDER (Interreg III); and
- the Mignot mill in Sirod (39).

Located on the Ain River, this former flour mill, which was shut down in 1985, has been subject to major renovations to convert it into a hydropower plant. The total investment in the renovation is approximately 200,000 EUR. ADEME and the Regional Council of the Jura region subsidised the project with an amount of 35,000 EUR.

a) Le Viaduc plant in Foncine le Bas (39).

This former hydro plant was shut down in 1994 and is located on the Saine River. The facility has been renovated. The associated water regulations have been renewed for a 30-year period. The weir, whose height is equal to the head, was cleared of sediment and the materials reused for the renovation works. The site rehabilitation also involved the reconstruction of the mill and the tailrace. The total investment is 300,000 EUR. A subsidy of 56,000 EUR was allocated to this project: 50% by the ADEME and 50% by the Regional Council of the Jura region.

b) Installation of a 75 kW hydropower plant in Gommeville (21).

The town of Gommeville purchased the Verniquet mill located on the Seine to rehabilitate it in order to produce electricity. A feasibility study was carried out and financed by the PECB, and compared various technical solutions.

The total cost of the project was 502,896 EUR. The subsidy calculation base was 281,074 EUR, and the grant proposed by the ADEME was 65%. In addition, the Regional Council of the Côte d'Or region granted 59,030.81 EUR. Self-financing through loans totalled 331,435.73 EUR. The annual production should average 340,000 kWh, the equivalent of saving 29.23 TOE and the prevention of 40,800 kg of CO_2 emissions. The kWh produced will be purchased (most likely) by EDF at 0.10 EUR. The annual income expected is 34,000 EUR.

3.5.4. Commercial loans and financing in France

France Hydro Electricité notes that banks are somewhat reluctant and demand excessive guarantees to finance projects that benefit guaranteed feed-in tariffs for 20 years. The guarantees generally required by banks are:

- Security in the form of company shares, the equipment, the feed-in tariffs, the delegating of insurance indemnities and potential indemnities related to the construction and/or maintenance contract, prefectural authorisation, EDF feed-in tariff invoices.
- Guarantees from the parent company, the personal liability of the project owner.
- An emphyteutic lease and related mortgage.
- Surety from one or more engineering firms defining the expected turnover and the completion of works within schedule.

Funding conditions for a small project under 500,000 EUR:

- A minimum equity of 20% (see above*).
- Separate funding of the construction and installation works, especially if the operator is not the owner.
- Assignment of EDF receivables under the Dailly Law mechanism.
- Personal surety of the managing director.
- Mortgage on the land as security.

Funding conditions for a project over 500,000 EUR:

- Equity equal to at least 15% of the amount borrowed.
- Guaranteed feed-in tariffs or daily transfer of receivables.
- A pledge of the holding shares of the company or the personal surety of the managing director.
- Partial mortgage guarantee on the land.
- An escrow arrangement on a reserve account.
- Application fee (~7,000 EUR for each 1,000,000 EUR loaned), payable in cash.
- An APR of 6% (whereas the conventional rates for real estate are 3.5%).
- Audit by a legal consultant.
- All-risk insurance covering project manager and contractor.
- Third party and inherent defects insurance.
- Project management contract with a commitment as to the budget, schedule and production.
- Emphyteutic lease.
- Maintenance of the DSCR above 105% during the loan period.

Funding conditions have become stricter since 2011 and obtaining finance has become difficult.

The role of the BPI is perceived differently by small, isolated investors and experienced industrialists. For critical-sized SMEs, the BPI may be a driver in creating and leading banking pools.

More and more often, bankers demand BPI co-financing before they will grant a loan. Finance packages then become more complex, creating an extra syndication cost (to organise loans among different banks), which is quite a burden for small projects.

Hydro power is not always considered for priority funding by the BPI, some of whose agencies consider it to be a mature sector, with little innovation, job creation and revenue generation.

a) General comments on funding difficulties.

Hydropower, and renewable energy sources in general, suffer from the fact that the sector requires major indebtedness over long periods; which means the realisation of shareholders equity during an unfavourable regulatory context (Basel III). Furthermore, the technicality of the sector requires major means and skills for the extended study and project set up. Also, RES generates limited cash flow in relation to the amounts loaned.

The usual commercial services of the private banks are organised to lend smaller amounts over shorter periods, to projects that are less technical and agreed on quickly to recover higher income flow through interest only-loans. Therefore, they do not perceive hydropower projects as being very appealing, even though the loans are profitable.

The problem is, that within major banks there are in fact services to respond to such requests (technical project set-up, long-term loans, limited cash-flow to recover in relation to the amount of the loans), but these are specialised structured financing services (investment banking) which do not grant loans under 15 or 20 million EUR, therefore application fees are very high. A discrepancy exists between the complex requirements of the banking procedure and the scope of small hydro projects. The financial crisis has only served to highlight this situation.

The BPI can fill this role, but is more willing to do so for medium-sized projects. They seem less effective or interested in smaller projects.

Hydro power is a highly capital-intensive sector that does not fit within the current goals of the finance sector, which requires a return on investment within a three to five year period.

3.6. Funding options in Greece

In this section, the funding options in Greece are provided. Especially in the past, there has been a large variety of options for financing small hydro plants. But the present reveals a different situation, since most of the funding is accomplished only by private sector, as is the case with most renewable energy installations, since subsidies and public support actions are limited.

In the past, both public (from EU and national funds) and private sector participated in the financing of small hydro plants (and more generally of RE systems). This financing can be divided into two main financial resources:

- governmental/public/European incentives; and
- other financial resources.

Governmental incentives deal most of the times with feed-in tariffs, subsidies, payback and tax regulations, such as special tax treatment/relief, attractive subsidies for SMEs and appropriate measures for the creation of new jobs, etc.

The most popular incentive is the use of feed-in tariffs. The electricity produced by the small hydro plants is sold to the electric grid operator with a pre-defined price (feed-in-tariff), set by national laws. This tariff has been decreased during the last years, following the general trend of renewables. This might seem unfair to such technologies, since their investment cost has not decreased, in comparison to other RES, such as PV and wind turbines. This is the reason that during the last six years very few licenses for new small hydro plants have been produced in Greece. Nevertheless, there is still margin for investors to implement win-win projects for all players involved.

3.6.1. Examples of RES/micro hydro cooperative projects in Greece

Currently in Greece there is no cooperative project relevant to hydro plants. The first one will be developed within the RESTOR Hydro project and will be established in the North of Greece.

Moreover, few such projects exist relevant to other RES types in Greece. The most common ones are for biogas production and use, where technology providers and developers cooperate with local agricultural associations, such as the Energy Cooperative of Karditsa (ESEK) in the North of Greece. Such projects are mostly relevant with biogas/biomass applications, since the agricultural sector has lots of wastes and by-products, which should be further utilised, according to the latest European directives.

3.6.2. ESI Funds for micro hydro in Greece

European funds have financed small hydro plants in Greece in the past. These funds actually paved the way for the private sector to get involved in such applications, since up to that moment only the Public Power Company (PPC) had the available resources to proceed to such investments (of both small and large scale). The European financial mechanisms for the hydro plant investments are briefly mentioned next.

a) European Investment Bank (EIB).

The European Investment Bank is a public institution within the European Union, financing priority projects (of both public and private sector), which meet EU policy objectives. Its main goal is to finance investments promoting economic development in the less favoured regions of the European Union, including RE plants, and especially hydro.

b) European Regional Development Fund (ERDF).

The European Regional Development Fund is one of the Structural Funds of the EU, which co-finances actions (providing subsidy) to help reduce the gaps in socio-economic development between the various regions and member States of the Union, aiming at disadvantaged regions. In such financial support scheme, actions for supporting RES projects (including small hydro plants) are eligible.

c) European Investment Fund (EIF).

The European Investment Fund is a financial institution, and offers guarantees on debt finance and invests in venture capital funds, focusing on European infrastructure projects in the areas of telecommunications, transport and energy. SMEs are also supported by this fund.

Nine small hydro projects in total have been developed in Greece with the aid of European structural funds during the period 1994-1999, as part of the European Union supported programme for developing renewable energy systems. One of its aims was the support at regional level and the creation of local jobs. The financial incentive was 45% of the total initial cost (total project costs around 17 million EUR), while the rest was provided by the private sector. The total power capacity of these projects is 11.5 MW and they are situated in the departments of Ioannina (Anatoliki, Anthochori, Mikro Peristeri and Distrato), Arta (Theodoriana), Karditsa (Vatsounia), Serres (Agkistro) and Laconia (Selegoudi).

The example of these projects encouraged potential investors to deal with small hydro projects, most of the times with the use of strong subsidies.

3.6.3. Grants and regional loans in Greece

There have been two main financial-support instruments that provide substantial public subsidies to RES investment projects and more specifically to small hydro plants:

- the so-called National Development Laws; and
- the Greek Operational Programme for Competitiveness, within the Third Community Support Framework (CSF III, duration: 2000-2006) for Greece.

Public sector is mainly providing grants to various investors, to a variable extent (even up to 50-60% of the initial costs of the investment) and with regard to a wide range of technologies for RE installations. Recent actions of grants and regional loans that have been completed are mentioned next.

a) National Operational Programme for Competitiveness (CSF III), Action 2.1.3.

The provider was the Greek Ministry of Development, including public/private sponsorships, (http://en.3kps.antagonistikotita.gr/epan/site/Home/t_section) and the area of applications covered renewables, the rational use of energy and small-scale cogeneration (lower than 50 MWe). This measure came into force in 2000 and provided

public grants (subsidies) to private investments during the period 2000-2006. For small hydro applications the subsidy is 40% of the total eligible investment cost.

b) National Development Law (Law 2601/1998).

This was the first such Law, with which significant effort was given on the increase of the RES penetration, including small hydro plants. The subsidies provided were around 40% of the investment, depending on the developer and the installation area. This Law was actually the first step in further increasing the use of renewables in Greece, engaging private investors.

c) National Development Law (Law 3299/2004).

The provider was the Greek Ministry of Development (including public/private sponsorships) and the area of applications covered RES installations for both electricity and heat production. This measure came into force in 2004 and provides public grants (subsidies) to private investments and in particular for SMEs, industries, and even for households. This action is actually a financial instrument, covering all private investments in Greece, in all kind of economic activities, showing a significant regional character, since the level of subsidy depends strongly on the geographic region of the planned investment. This measure promotes investments in regions with high unemployment rates and low incomes per capita.

d) National Development Law (Law 3908/2011).

The Development Law that came into force in 2011 provides financial support for private investors for RES investments. The potential investor could submit an application during two periods per year (deadline in April and October), while for large projects the application platform was open the whole year. The support includes tax relief measures, subsidy, or leasing subsidy, or even a combination of these three actions.

e) National Development Law (Law 4146/2013).

Currently, a new investment law is valid National Development Law14, being valid from March 2014 and onwards (up to 28th of February 2014 applications are submitted based on the previous Development Law, Law 3908/2011), which states that the incentives provided for installation of small hydro plants deal only with tax exemption measures (no grants or subsidies, just a tax relief), according to the installation area and the size of the enterprise that intends to proceed to such investment. Especially for large-scale hydro plants, which include pumped hydro storage facilities, and biogas/biomass investments subsidies can be also provided.

f) National Fund for Entrepreneurship and Development (ETEAN).

The ETEAN fund focuses mostly to SMEs and aids in the provision of finance for the implementation of various projects up to half a million euros. Such fund does not focus solely to RE plants, but is also relevant to entrepreneurship, agriculture, etc. It is co-

[14] http://www.investingreece.gov.gr/default.asp?pid=180&la=1

funded by the Operational Programme "Competitiveness and Entrepreneurship" (http://epan2.antagonistikotita.gr/english/programme.asp) and other NSRF programmes supported by the European Regional Development Fund and the European Fisheries Fund (http://www.investingreece.gov.gr/default.asp?pid=87&la=1). ETEAN is designed to improve the access of finance to enterprises for their development, to help create new enterprises, to enable and enhance productivity, and to facilitate the entry of new products and services to market, by granting loans with favourable terms (low interest rate) to finance investments made by organisations in the sectors Thematic Tourism, Desalination, Waste Management, Green Infrastructure, Green Applications, and Renewable Energies.

g) Fast Track Law.

Another financing mechanism, which however targets larger scale investments on RES, is the so called Fast Track Law and has been put to force in Greece, since the beginning of the economic crisis in 2010. The Law 3894/2010 on Acceleration and Transparency of Implementation of Strategic Investments (http://www.investingreece.gov.gr/default.asp?pid=215&la=1), focuses on strategic investments, which can generate significant results (in terms of budget, new jobs, innovation, etc.) of major significance for the national economy, while having positive multiplier effects, and can help the exit from the economic crisis. Several such projects have been accelerated, while only one was relevant to hydroelectricity, although of large-scale (hydroelectrical power generation and pumped-storage complex in Aetoloakarnania with capacity of 587 MW).

h) Examples of small hydro plants financing with public grants and support.

During the period 1998-2001, the Development Law supported the implementation of 12 investments of small hydro with total capacity 35 MW. While the program Operational Program Energy under the 2nd Community Support Framework (CSF) financed 9 more investments of a total capacity of 11.5 MW during the same time period. The Operational Programme Competitiveness during the period 2000-2006 continued to finance small hydro projects under the Action 2.1.3.

Concerning large hydro investments (including pumped-storage units) their installed capacity reached 3,010 MW in 2003, operated by PPC (the public power company). In the period 1997-2003, 8 additional units of total capacity 533.6 MW were integrated into the interconnected system, while 9 more hydroelectric power plants of total capacity 320.6 MW have been implemented during the period 2004-2009. Based on implemented and adopted policies and planning, it is estimated that the total installed capacity of hydro units (both small and large ones) in Greece will amount to 3,732 MW in 2015, due to the high hydro potential (around 300 MW for the small ones, http://www.lagie.gr/systima-eggyimenon-timon/ape-sithya/adeiodotiki-diadikasia-kodikopoiisi-nomothesias-ape/).

3.6.4. Commercial loans and financing in Greece

The private sector is offering loans specifically tailored for RE systems, having similar characteristics with a wide range of applications, size and technologies (energy saving, insulation, solar water heating, geothermal, new generation boilers and air-conditioning systems, photovoltaic plants not connected to the grid and RET in general) and targeting either households, industry or SMEs. Both financing limits and terms vary according to specific projects and are subject to each case.

Such support usually aims at the initial financing of the plant, which means to provide a financial aid for the initial investment, which is the main cost for RE systems and especially for small hydro plants.

The most popular financing of hydro plants is by long-term loans from national banks. Such method is the most common one for all RES projects, while different banks offer various alternatives, according to the scale, risk and maturity of each business plan. For low-risk projects, project finance is followed, where a bank actually finances a great amount of the initial costs and receives the assets of the project as a guarantee.

Finally, third-party investors can also finance a RE project (http://www.biogasin.org/financing.html). Such method is new and has some interesting features and advantages. A third-party undertakes the financing of a project and in some cases its implementation as well (licence, design, construction, operation, etc.). Third-parties could be an Energy Services Company (ESCO) company or even a business angel[15]. However, both parties usually focus on very small projects, usually with a budget lower than 100,000 EUR, which can be restrictive for the case of small hydro plants.

3.7. Funding options in Italy

Through the last 20 years, in Italy, the actual drive to develop SHP plants and RES projects was provided by several schemes to support the production of renewable electricity issued by the national Government.

Unfortunately, over the past five years the incentive framework has been modified many times and currently many different support schemes are overlapping, thus creating confusion and uncertainty among investors (especially the smallest ones).

Anyway, the last support scheme for renewable energy production introduced by Ministerial Decree 06/07/2012 provides high incentives and lighter procedures for smaller plants: HP plants with a capacity (P) of less than 50 kW have direct access to a comprehensive feed-in tariff without going through the registry system (this limit is raised to 250 kW in case of HP plants realised on existing channels or pipes without increasing the flow rate), the FIT is paid for 20 years and for plants with P less than 20 kW commissioned in 2014 the FIT is 251.86 EUR.

[15] Informal Investors or *business angels* tend to invest locally and in business sectors, in which they already have some experience. In general, they apply less restricted investment criteria and may have lower outcome than capital funds. Such model is appropriate for small hydro plants, where the local characteristics play a major role. Nevertheless, a significant drawback could be the limited size of investment at such cases, which might be restrictive.

Moreover, a specific exemption to the general provision on prevention of incentives overlapping is provided for very small RES plants: incentives provided for the energy production can be cumulated with the access to guarantee funds and other public grants (up to 40% of investment costs in case of plants with capacity up to 200 kW).

Of course, incentives for the electricity production can help to reduce the payback periods of this kind of projects; anyway, all hydropower projects always require a significant initial investment.

Different approaches can be observed when monitoring this aspect: private owners basically tend to ask for a loan from a bank, while local administrations usually apply for public money (structural funds or national/regional grants). RES cooperatives, on the other side, are often able to collect at least a substantial amount of the necessary money through fund-raising activities or shares' trading among their members.

3.7.1. Examples of RES/micro hydro cooperative projects in Italy

Small renewable energy cooperatives can play a multiple role: grouping citizens together and establishing an agreement with local communities, collecting the necessary funds and redistributing incomes or other benefits directly on the territory.

Within the Alps arch, we can still find today some historical electrical cooperatives established in the first half of 1900, which manage both HP plants and local distribution grids[16].

These cooperatives represent an exception to the present legal framework, which do not allow a producer to directly distribute and sell electricity to end users.

Besides these traditional cooperatives, nowadays we are witnessing the growing of new RES energy cooperatives models, constituted by enthusiastic and aware citizens, who basically care for renewable energy and distributed generation issues and decide to join forces.

These new entities, sometimes not formally registered as traditional cooperatives but as non-profit associations or social enterprises, are often based on web and social networks interaction between their members: this allows for a territorial coverage wider than merely local, even if local clusters are frequently built for the management of single projects.

An example of this is new model of RES cooperative is Retenergie (www.retenergie.it) who started realising photovoltaic plants, but is now approaching also mini hydropower plants[17]. A SHP of around 75 kW equipped with an Archimedes screw is currently underway near Reggio Emilia (estimated production: 170,000 kWh/year) and the restoration of an old mill near Treviso is under evaluation with the support of the RESTOR Hydro project.

[16] http://www.federconsumo.confcooperative.it/Elettrico/Pagine/SettoreElettrico.aspx
[17] http://www.retenergie.it/index.php?option=com_content&view=article&id=46&Itemid=78

Another interesting experience is the *Comunità Cooperativa di Melpignano*[18] founded in 2011. Melpignano is a small village in the South of Italy in Puglia where many of its citizens joined together in a community cooperative with the main scope of realizing a sort of collective PV plant distributed on the different suitable roofs of its members. Presently the cooperative can count on 136 members and already invested 400,000 EUR to realise the first 33 PV plants, for a total installed capacity of 179.67 kW. The cooperative members who host a PV plant on their roofs can have free electricity for 20 years, while the incentives received from the Energy System Manager (GSE) are turned to the cooperative that invests them for local projects. Moreover the project activated a virtuous cycle, since local workers were employed to project and install the PV plants.

Also within the solidarity based purchasing groups (*Gruppi di Acquisto Solidale,* G.A.S), there is a big interest for renewable energy and energy saving issues and some local GAS are considering investing money in small RES plants.

3.7.2. ESI Funds for micro hydro in Italy

No information can be found about SHP plants financed through EU funds in the past two or three decades.

Analysing the last cycle of EU investment programmes (2007-2013) and in particular the interregional operative programme (POI) Renewable Energy and Energy Efficiency approved by the Italian Government, we can find some examples of projects referred to biomass (Lombardia Region) and wind off-shore (Marche, Abruzzo, Molise, Puglia).

More info about these projects can be found on these websites:

- http://ec.europa.eu/regional_policy/country/prordn/details_new.cfm?gv_PAY=IT&gv_reg=ALL&gv_PGM=1040&LAN=10&gv_PER=2&gv_defL=7
- http://www.poienergia.gov.it/

3.7.3. Grants and regionals loans in Italy

Despite the existence of interesting support schemes for the production of electricity from RES, which often could not be cumulated with other kind of public grants or aids, in the last years some regional grants for the realisation of SHP plants (covering a percentage of the investment costs) were anyway issued.

These grants were often addressed to specific sectors or categories of SME, like for example small agricultural enterprises or tourist structures or even public institutions.

The choice of applying for a public grant instead of the incentives for the electricity production can be valuable in case the electricity is self-consumed directly on-site, thus reducing the electricity bill.

Some examples of these kinds of grants can be found at this link: http://enerweb.casaccia.enea.it/enearegioni/UserFiles/Fontirinnovabili/bandi/bandi.html

[18] http://www.coopcomunitamelpignano.it/

Recently another initiative was launched by the Ministry of Agriculture and Forestry through the special agency Agensud to finance the realisation of SHP along the network of channels owned by Irrigation Consortia in the Center/South of Italy. More info can be found at this link: http://www.gestcomagensud.it/index.php/it/bando-centro-sud

3.7.4. Commercial loans and financing in Italy

Many banks of the private sector are presently offering loans specifically tailored for RE systems and targeting households, industry or SMEs. Both financing limits and terms vary according to specific projects and are often evaluated case by case.

Anyway, there are two financial institutions that, for their statutory mission, are especially committed to finance small RES projects: Banca Etica and Credito Cooperativo system.

a) Banca Etica.

Manages savings raised from private citizens, organisations, companies and institutions in general, and invests them in initiatives pursuing both social and economic objectives, operating in full respect of human dignity and the environment.

The real capital of the Bank is represented by its shareholders, by the trust they put into the project of the Bank. Banca Etica grants financing to organisations operating within the third sector which carry out socially oriented economic projects, having the legal form of cooperative societies, associations or social institutions, operating in one of the following areas: social cooperation, international cooperation, environment (alternative and renewable energy sources).

Within the special project *Progetto Energia*, Banca Etica offers some financial products specifically addressed to the realisation of small/medium RES plants, including special loans for private citizens and for organisations and companies[19].

b) Credito Cooperativo.

Credito Cooperativo is a system based on a network of 388 cooperative banks called Banche di Credito Cooperativo, Casse Rurali and Casse Raiffeisen (in Alto Adige), some associative structures and several service companies, all working together to guarantee a complete and diversified range of products, in keeping with the values and identity of a cooperative. The most important feature of these cooperative banks (BCCs) is that of being local, mutual, not-for-profit cooperatives.

The BCCs are double sided banks: they act both as financial intermediaries, with their fundamental activities of loans and savings accounts, and as Corporate Social Responsibility (CSR) companies: their primary objectives are the wellbeing of their stakeholders and the development of the local economy.

In 2006 an agreement was signed with Legambiente, one of the major Italian environmental associations; to offer special loans for the realisation of small RES plants[20].

[19] http://www.bancaetica.it/progetto-energia

Recently, also crowdfunding (a new way to collect money from citizens based on web platform) is coming on stream in Italy and its application for the implementation of small RES plants seems very interesting and well fitting.

3.8. Funding options in Lithuania

As previous experience shows, in the past and present most funding of SHP projects was accomplished only by the private sector, since subsidies and public support actions are very limited. Moreover, there is commonly prevailing opinion in the country, that RES installations generating power are already entitled to the support benefiting from the feed-in tariffs and any other incentive be it a financing part of investment cost for construction of a SHP would be a doubling public support, which might distort the power market competition.

3.8.1. Examples of RES/micro hydro cooperative projects in Lithuania

There is no cooperative project running hydropower plants in Lithuania. The same situation is prevailing for other RES projects (i.e. wind, biomass etc.). In contrast, agricultural, trade and banking (credit union) cooperatives, which have long lasting traditions dating back before World War II (WWII), are quite numerous in the country. For instance, some 220 small agricultural cooperatives are currently acting on the market.

Recently a first cooperative for developing a small hydro plant on the existing dam has been founded in the country initiated by the RESTOR Hydro project and next two are on the pipeline.

3.8.2. ESI Funds for micro hydro in Lithuania

The Structural Funds and the Cohesion Fund in 2007-2013 aimed at the support of innovative energy actions in the country through the promotion of RES and rational use of energy. However, they did not provide direct financial support for power generation from RES plants; a priority was given to the heat production facilities using biomass. SMEs were also supported by these funds, but no small hydropower has been developed under this line so far.

In contrast to the above mentioned statement, a number of water mills benefitted from the EU structural fund in terms of renovating them in order to strengthen the cultural heritage and attract tourists. A couple examples given below illustrate successfully implemented projects.

Before WWII, there were more than 13 water mills in operation on a small river Virvyte, located in western part of the country. In 2010, one of them, Angelu water mill (Kulio Daubos village) was renovated with the aid of the SCF to adapt for the tourism purposes, including enhanced water recreational potential. The water mill is officially listed as an object of cultural heritage and is now hosting a museum. Some 400,000 EUR were allocated as part of co-financing for this renovation. The water mill area is closely

[20] http://www.creditocooperativo.it/template/default.asp?i_menuID=36285

associated with Baltininku SHP (capacity 0.4 MW) commissioned using private investments in 2008. Its head pond (surface area of 40 ha) is abundant in fish resources. The hydro schemes are located in Varniai regional park. This project clearly demonstrates a good example of synergy for the promoting the power sector and cultural heritage including enhanced eco services.

Ginuciu water mill (the Srove river, Ignalina district) also benefited from the SCF for adapting cultural heritage objects for the promotion of tourism. Some 200,000 EUR were co-founded into water mill renovation and clearing up the surrounding area. The old water mill equipment was conserved and actually it is exhibited for general public. The owners are considering installing a micro hydropower plant (capacity some 20 kW).

More information: http://www.lvpa.lt/dokumentai/leidiniai/GIDAS_LT.pdf

The rural Development Program 2007–2013 well defined aims were intended to support financially small RES projects. Young farmers, people promoting recreational services and development of tourism in rural areas or even those shifting from primary agriculture production to other kind of business could benefit the support. Small hydropower projects were also eligible under this program. Unfortunately due to the specific rules for applying for this program (i.e. only off-grid or self-consumption of the power produced) only a few of them with a marginal support were able to get the funding during the program life cycle. More information: http://www.nma.lt/index.php/parama/lietuvos-kaimo-pletros-2007-2013-m-programa/apie-programa/17

3.8.3. Grants and regionals loans in Lithuania

The Lithuanian Environmental Investment Fund (LEIF) provides soft loans for the financing of environmental projects the implementation of which reduces the negative impact of economic activities on the environment, and subsidies for the financing of renewable energy projects. During the period 2000-2005, the LEIF has financed seven small capacity projects which provide for generation of electricity from renewables. Five of these were hydro power plants construction projects (the aggregate installed capacity is around 1 MW). The amount of the subsidy for one beneficiary did not exceed 100,000 EUR (70% of the total investment amount). More information: http://www.laaif.lt/

Restoration of the Liubavas Manor watermill (Vilnius, Zalesos river) and its adaptation for a museum started in 2008. For this purpose a number of funding was used including EEA, Norway, and Switzerland grants. Recently a micro hydro plant (P=20 kW) has been installed to generate power. By doing so there is a clear added value for the overall project. The owner, Public Institution Europos Parkas, is propagating the use of renewable energy sources by exhibiting old and nowadays equipment. More information: http://www.liubavas.lt/

Some state aid could be allocated also for privately owned water mill. Maslauskiskai water mill (the Dubysa river, Raseiniai district) is privately owned, and is officially listed as an object of cultural heritage. In 2012, only its building was refurbished using financial contribution of the Department of Cultural Heritage. The owner was refused to get the

consent for installing a micro hydropower plant on this river, because it is listed as an ecologically and culturally valuable river and belongs also to a designated area. Anticipated plant capacity is 180 kW and expected before tax profit would be some 100,000 EUR annually.

In 2014, Pasvalys municipality submitted a proposal to the Department of Cultural Heritage in order to get funding for the restoration of Rauboniai water mill (the Tatula river). The water mill is located in designated area (landscape reserve) and the river is listed as an ecologically and culturally valuable river. It is expected to adapt this water mill for promotion of the local tourism sector. For the moment there are no plans to install turbines, which capacity could reach 60 kW.

More information: http://www.kpd.lt/lt/category/16/142

3.8.4. Commercial loans and financing in Lithuania

As previous experience shows, in the past and present most funding of SHP projects was accomplished only by the private sector, since subsidies and public support actions are very limited. The most popular financing of SHP plants was long-term loans from national banks.

3.9. Funding options in Poland

3.9.1. Examples of RES/micro hydro cooperative projects in Poland

There are no known small hydro plants cooperative projects with private entities in Poland in a direct manner.

Anyway, there are a number of non-direct cooperative projects where the main weir is built by governmental entity and the plant by a private one. On a daily basis the plant owner is responsible for the public hydro-equipment (i.e. weir, dam, vents, channels, etc.) operation in return of using it or the plant purposes.

The first cooperative will be provided by RESTOR Hydro project.

3.9.2. ESI Funds for micro hydro in Poland

European funds played a significant role in small hydro plants development in Poland. It helped in numerous hydro investments (RES and non-RES) in Poland. The coming financial perspective for 2014-2020 opens new financing potential.

Currently all operational programmes are during consultancy phases. In the case of the Polish Management Authority tasks are passed to voivodship level.

After analysis of the draft documents mentioned above it can be concluded that projects related to development, reconstruction and modernisation of RES are planned for every operational programme. The most common objectives, planned for financing and relevant for small hydro plants are:

- RES share increase;

- distributed energy sources;
- small retention growth; and
- flood and drought protection.

Operational programmes are mostly dedicated to local government units and entrepreneurs. Specific allocations are not known yet.

The table below contains the list of responsible agencies managing the operational programmes in Poland.

Voivodship	Responsible agency
zachodniopomorskie	Urząd Marszałkowski Województwa Zachodniopomorskiego Korsarzy 34 Str, 70-540 Szczecin www.wzp.pl Wydział Zarządzania Regionalnym Programem Operacyjnym Wyszyńskiego 30 Str, 70-203 Szczecin Tel.: (91) 44 11 171
pomorskie	Urząd Marszałkowski Województwa Pomorskiego Okopowa 21/27 Str, 80-810 Gdańsk Departament Programów Regionalnych Augustyńskiego 2 Str, 80-819 Gdańsk Tel.: (58) 326 81 33 www.dpr.pomorskie.eu
warmińsko-mazurskie	Urząd Marszałkowski Województwa Warmińsko-Mazurskiego Emilii Plater 1 Str, 10-562 Olsztyn Departament Zarządzania Programami Rozwoju Regionalnego Kościuszki 83 Str, 10-950 Olsztyn Tel.: (89) 52 19 637 , (89) 521 96 00, (89) 521 96 99 www.rpo.warmia.mazury.pl
podlaskie	Urząd Marszałkowski Województwa Podlaskiego Kardynała Stefana Wyszyńskiego 1 Str, 15-888 Białystok Departament Zarządzania RPO Poleska 89 Str, 15-874 Białystok Tel.: 0 8013 0 8013, 85 66 54 399 www.rpowp.wrotapodlasia.pl
mazowieckie	Urząd Marszałkowski Województwa Mazowieckiego Departament Strategii i Rozwoju Regionalnego al. Solidarności 61 Str, 03-402 Warszawa Tel.: (22) 597 97 51, (22) 597 97 55 www.mazovia.eu

kujawsko - pomorskie	Urząd Marszałkowski Województwa Kujawsko-Pomorskiego Pl. Teatralny 2 Str, 87-100 Toruń Departament Zarządzania Funduszami i Projektami Unijnymi M. Skłodowskiej-Curie 73 Str, 87-100 Toruń Tel.: 56 656 11 30 Departament Wdrażania Regionalnego Programu Operacyjnego Pl. Teatralny 2 Str, 87-100 Toruń Tel.: (56) 62 18 700 www.fundusze.kujawsko-pomorskie.pl
wielkopolskie	Urząd Marszałkowski Województwa Wielkopolskiego Al. Niepodległości 16/18 Str, 61-713 Poznań Departament Polityki Regionalnej Szyperska 14 Str, 61-754 Poznań Tel. (61) 626 63 00 Departament Wdrażania Programu Regionalnego Szyperska 14 Str, 61-754 Poznań Tel.: (61) 626 61 00, (61) 626 61 92, (61) 626 61 93 www.wrpo.wielkopolskie.pl
lubuskie	Urząd Marszałkowski Województwa Lubuskiego Podgórna 7 Str, 65-057 Zielona Góra Wydział Programowania Strategicznego Departamentu Lubuskiego Regionalnego Programu Operacyjnego Podgórna 7 Str, 65 - 057 Zielona Góra Tel.: (068) 45 65 394 Departament Lubuskiego Regionalnego Programu Operacyjnego Św. Jadwigi 1 Str, 65-065 Zielona Góra Tel.: (068) 333 44 00 www.lubuskie.pl
dolnośląskie	Urząd Marszałkowski Województwa Dolnośląskiego Wybrzeże Słowackiego 12-14 Str, 50-411 Wrocław Helpline: (71) 776 91 42 or (071) 776 91 20 Departament Regionalnego Programu Operacyjnego Tel.: (71) 776 91 53 Wydział Zarządzania Regionalnym Programem Operacyjnym Tel.: (71) 776 93 35 Wydział Wdrażania Regionalnego Programu Operacyjnego Tel.: (71) 776 90 41 www.rpo.dolnyslask.pl

opolskie	Urząd Marszałkowski Województwa Opolskiego Departament Koordynacji Programów Operacyjnych Ostrówek 5-7 Str, 45-082 Opole Tel. (77) 54 16 565, 54 16 566 Helpline: (77) 44 04 720 www.umwo.opole.pl Opolskie Centrum Rozwoju Gospodarki ul. Spychalskiego 1a 45-716 Opole Tel. (77) 40 33 600 www.ocrg.opolskie.pl
łódzkie	Urząd Marszałkowski Województwa Łódzkiego Al. Piłsudskiego 8 Str, 90-051 Łódź Departament ds. Regionalnego Programu Operacyjnego Tel.: (042) 663 30 64 Helpline: (042) 663 31 07, (042) 663 34 05 www.rpo.lodzkie.pl Centrum Obsługi Przedsiębiorcy Roosevelta 15 Str, 90-056 Łódź Tel.: (042) 230 15 50 Helpline: (042) 230 15 55, (042) 230 15 56 www.cop.lodzkie.pl
świętokrzyskie	Urząd Marszałkowski Województwa Świętokrzyskiego Al. IX Wieków Kielc 3 Str, 25-516 Kielce Tel.: (41) 342 18 78 www.sejmik.kielce.pl Departament Polityki Regionalnej Sienkiewicza 63 Str, 25-002 Kielce Tel.: (41) 36 58 170 Departament Funduszy Strukturalnych Sienkiewicza 63 Str, 25-002 Kielce Tel.: (41) 36 58 100 www.rpo-swietokrzyskie.pl Helpline: (41) 343 22 95
śląskie	Urząd Marszałkowski Województwa Śląskiego Wydział Rozwoju Regionalnego Dąbrowskiego 23 Str, 40-032 Katowice Tel.: (32) 774 06 54 rpo.slaskie.pl Helpline: (032) 77 40 172 Śląskie Centrum Przedsiębiorczości

	Katowicka 47 Str, 41-500 Chorzów Tel.: (32) 743 91 60 www.scp-slask.pl
lubelskie	Urząd Marszałkowski Województwa Lubelskiego Spokojna 4 Str, 20-074 Lublin Departament Regionalnego Programu Operacyjnego Stefczyka 3B Str, 20-151 Lublin Tel.: (81) 44 16 738 Helpline: 0 800 888 776 Helpline over mobile: (081) 44 16 750 www.rpo.lubelskie.pl Lubelska Agencja Wspierania Przedsiębiorczości w Lublinie Wojciechowska 9a Str, 20-704 Lublin Tel.: (81) 46 23 831, 46 23 812 Helpline: (081) 46 23 831, (081) 46 23 812 www.lawp.eu
podkarpackie	Urząd Marszałkowski Województwa Podkarpackiego al. Cieplińskiego 4 Str, 35-010 Rzeszów Departament Rozwoju Regionalnego Tel.: (17) 747 64 66 Departament Wdrażania Projektów Infrastrukturalnych Regionalnego Programu Operacyjnego Tel.: (17) 747 65 00 Departament Wspierania Przedsiębiorczości Towarnickiego 1A Str, 35-010 Rzeszów Tel.: (17) 747 61 70 www.wrota.podkarpackie.pl/pl/rpo
małopolskie	Urząd Marszałkowski Województwa Małopolskiego Departament Polityki Regionalnej Wielicka 72 Str, 30-552 Kraków Tel.: (12) 29 90 900 Helpline: (12) 29 90 740 www.fundusze.malopolska.pl/rpo Małopolskie Centrum Przedsiębiorczości Jasnogórska 11 Str, 31-358 Kraków Tel.: (12) 376 91 00 www.mcp.malopolska.pl

3.9.3. Grants and regionals loans in Poland

National Fund for Environmental Protection and Water Management (*PL Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej*; http:// http://www.nfosigw.gov.pl) and

Regional Funds for Environmental Protection and Water Management (*PL Wojewódzkie Fundusze Ochrony Środowiska I Gospodarki Wodnej*).

The Fund provides financial support mostly for projects, which implement environmental obligations of Poland transpiring from the membership in the European Union. It offers a variety of environmental products and focus areas.

From the small hydro plants development point of view the most important areas are protection of water and water management, energy efficiency and renewable energy. The financing is carried out by number of mechanisms used by the Fund. The most commonly used are: investment grants, interest-based loans including loans granted by banks, payments for loan interest, loan extinction, etc.

Currently the most interested mechanism for small hydro plants is a priority programme called Bocian dedicated to distribute RES. Planned for 2014–2022. The basic assumptions are:

- financing up to 50% of the initial cost;
- maximum project cost is up to 25 million PLN (around 6 million EUR) per 1 MW; and
- small hydro plants up to 5 MW.

The programme was opened in March 2014.

a) Norway grants: Green Industry Innovation Programme for Poland.

(http://www.norwaygrants-greeninnovation.no)

It is a business development programme aiming to increase the competitiveness of green enterprises, including greening of existing industries and green innovation. The programme operator is Innovation Norway, a state owned company under the Norwegian Ministry of Trade, Industry and Fisheries and the Norwegian County Municipalities. The program is dedicated to SMEs, which plans (alone or with Norwegian partner) projects related to the environment improvement. Activities to be supported are development, implementation, investment and training related to environmentally friendly technologies, production processes, innovative green products and services, reduction and re-use of waste, initiatives related to energy efficiency and more use of renewable energy in business operations, as well as increased resource efficiency through system and process innovation in the business operations (small hydro plants are in scope). The minimum grant amount is 170,000 EUR, maximum is 1,500,000 EUR. The next grant opening is planned for the March 2014.

b) Rural Development Foundation (*PL Fundacja Wspomagania Wsi*)

(http://www.fww.org.pl)

It is a non-governmental organisation carrying out diversified activities in Polish rural areas. One of these activities is micro loans for small hydro plants refurbishments (especially water retention restoration). Simple procedures and very good loan

conditions provided a real contribution in small hydro plants development in the past 30 years. The basic parameters are:

- term of loan: 5 years with 1 year grace period;
- maximum amount of the loan is 200,000 PLN (around 50,000 EUR); and
- interest-free loan (0.0%).

The program is on hold at least until June 2014.

3.9.4. Commercial loans and financing in Poland

a) Banks offerings.

There are number of commercial offerings for RES financing on the Polish market. The most popular programmes (long-term loans) are provided by commercial banks. The offerings are similar and easy to compare. The following table presents the basic loans parameters offered on the Polish market in the first quarter of 2014.

	Basic commercial banks offerings	Most popular scenario for small hydro plants*
Currency	PLN	
Own contribution (of the initial costs)	From 15%	Around 30%
Term of loan	Up to ~20 years for buildings Up to ~10 years for equipment	15 years for the whole project
Loan bank margin	From 3.5%	3.7% – 4.2%

* based on TRMEW screening done in February 2014

b) Project financing.

There are number of private equity capital funds operating on the Polish market which are focusing on searching, evaluating, preparing and executing RES projects. The funds are rather looking for RES projects within the budget over 1 million EUR and less than eight years payback period.

c) Green certificates prices instability.

Starting from the middle of 2012 Polish RES market began to have difficulties related to green certificates oversupply. In the critical momentum the prices fell to 40% of their long-term stable price. Currently the oversupply is getting lower, prices are rising and market is getting more stable. The situation caused that commercial entities had to:

- strengthen their requirements;
- increase loan rates for new offerings;
- ask for additional loan collateral;
- stop RES financing; and
- examine all projects financing applications.

Renovated SHP Kalisz (Credits: Ewa Malicka)

3.10. Funding options in Slovenia

In the past, both public and private sector participated in the financing of small hydro power plants. This financing can be divided into two main financial resources:

- the National Government or European public incentives; and
- the Private and other financial resources.

Governmental incentives may be of different kind, but have in the past mostly been feed-in tariffs, subsidies, payback and tax regulations, attractive subsidies for SMEs and appropriate measures for the creation of new jobs, regional development, etc.

In Slovenia the public financial fund Eco Fund (*Eko Sklad*) is offering the loans for environmental projects (renewable energy sources and energy conservation/efficiency) and providing the guarantees for commercial banks.

The second popular incentive is the use of premium based feed-in-tariffs. The electricity produced by the small hydro power plants can be sold to the national market operator (Borzen, Center za podpore) by the price (feed-in-tariff), set by the government and Energy Agency. The SHP operator can choose between the fixed price and the premium. Fixed prices include the forecasted market price and the premium and they are fixed for the period of 15 years. If he chooses the premium instead, it represents the difference between the annually forecasted market price and the total fixed price, but he needs to sign the electricity selling contract with a commercial energy trading company. The support system guarantees the priority grid access and the 15 years duration in order to secure the ROI.

The electricity market price has sunk in the past few years due to the effects of the economic crisis and consequently lack of demand (excess of electricity). The support system is therefore vital for the development of small RES and fair market conditions.

3.10.1. Examples of RES/micro hydro cooperative projects in Slovenia

Only a few small renewable energy cooperatives were established in the past in Slovenia. Mainly there were agricultural cooperatives that play a multiple role: grouping citizens together and establishing an agreement with local communities, collecting the necessary funds and redistributing incomes or other benefits directly on the territory.

Some fifty years ago there were several cooperatives established by the SHP owners on the same river or channel. The aim of such cooperative was to jointly manage the flow regime, provide the maintenance of the stream, and hydraulic equipment. Sometimes they were jointly supplying their electricity to the factory (i.e. paper mill) or selling it to the grid.

An example of a contemporary RES cooperative is Zadruga Soča-Trenta which started the limited liability company MHE Krajcarica to manage the SHP on the river Krajcarica with 2x300 kW installed power. The profit is reinvested in other local projects.

SHP Krajcarica refurbished Venetian sawmill (Credits: Zvonko Belic)

Besides these traditional cooperatives, nowadays we are witnessing the slight growth of new RES energy cooperatives, constituted by enthusiastic and aware citizens, who basically care for renewable energy and distributed generation issues and decide to join forces.

3.10.2. ESI Funds for micro hydro in Slovenia

Funding opportunities for small hydro power cooperatives in Slovenia are:

a) The European Social Fund.

An initiative of social entrepreneurship which provides funding to the cooperative shareholders and other stakeholders. Particularly in terms of labour costs, promotion and development of marketing channels.

b) The European Agricultural Fund, program LEADER.

Will primarily support projects with stakeholder participation in the creation of content activating unused potentials. In can provide the co-financing of project costs for the renovation, purchase of equipment and the activation of new jobs.

c) European fund for regional development and cross-border cooperation programs.

An integrated network of SHP co-operation project could be designed, which would cover the Eastern Slovenian region and would include both the area of investment, management jobs, technology and multipurpose sites.

We find the opportunity to implement the SHP cooperatives into the programming development of the regions and rural areas in each region separately or as integral content of operational programs. The key developers in this field must also sign a partnership agreement for the development of the regions, which will allow them the right to active participation.

3.10.3. Grants and regionals loans in Slovenia

In Slovenia the public financial fund Eco Fund (Eko Sklad) is offering the loans for environmental projects (renewable energy sources and energy conservation/efficiency) in accordance with the National Environmental Action Plan and the EU environmental policy.

Activities of the Fund are particular:

- Loans for investments in environmental protection by loans with favourable interest rates.
- Issuing of guarantees and other forms of guarantees for environment protection investments.
- Financial, economic and technical advice.
- Tasks relating to the implementation of environmental protection policies.

Eco Fund is granting credits for environmental investments on the basis of public tenders as:

- a loan program for the environmental investments of the citizens; and
- a loan program for environmental investments by legal entities.

From June 2008 to October 2009, the Eco Fund on behalf of the Republic of Slovenia confers a non-repayable financial incentives for citizens to invest in solar heating systems, complete renovation of one or two-dwelling buildings and low-energy or

passive new build housing and some specific measures in the context of the renewal of existing residential buildings.

Eco Fund will continue to provide grants program of financial incentives to individuals for activities in the field of energy efficiency and use of renewable energy sources based on the adopted decree on the provision of savings among final customers (Official Gazette of RS, št.114/2009), adopted by the Government the Republic of Slovenia on 30 December 2009 and applies from 1 January 2010.

In accordance with this decree the Eco Fund has prepared and asked the Government of the Republic of Slovenia to confirm a program for improving energy efficiency in 2010 in which the measures and incentives have been defined to achieve the energy savings at the end consumers. Public calls for the allocation of grant financial incentives have been published on 21st of May 2010 after the program was confirmed by the Government of the Republic of Slovenia on 13th of May 2010.

The program to provide grant financial incentives to individuals is continued on the basis of the program, approved by the Government of the Republic of Slovenia within the annual business and financial plan of the Eco Fund.

a) Program: loans for environmental investments by citizens.

The program was launched in May 1996, after the World Bank obtained credit in the amount of DEM 30 million. Funds were donated to co-finance transitions to cleaner sources of heat. The pilot phase was conducted a year earlier in Maribor. The funds of the World Bank project were expanded to the rest of Slovenia.

Eco Fund credited the following purposes:

- Installation of modern equipment and systems for space heating and domestic hot water.
- Use of renewable energy.
- Reduce heat loss in the reconstruction of existing housing.
- Construction of new low-energy residential buildings in which coefficient specific heat loss of the building shall not exceed 0.25 W/m2K.
- The purchase of energy efficient appliances.
- The purchase of environmentally friendly vehicles.
- Collection and treatment of waste water.
- Replacement of building materials containing hazardous substances.
- Efficient use of water resources.
- Drinking water supply.

b) Program: loans for environmental investments by legal entities.

Under this program, loans can be provided for investments resulting in reduction of greenhouse gas emissions, including:

- Modern appliances for space heating and domestic hot water, which exploit renewable energy sources.
- Facilities for power generation or cogeneration of heat and electricity from renewable energy sources.
- Facilities for cogeneration of heat and electricity from fossil fuels.
- Purchase of electric or hybrid vehicles on the road.
- Various energy efficiency measures in manufacturing, commercial and public buildings.
- Reconstruction of existing public lighting, in which to achieve adequate energy savings.
- Comprehensive renovation of existing facilities with demonstrated corresponding coefficient for heat loss.
- Construction of new low-energy buildings with a demonstrated corresponding coefficient for heat loss.

That counts as well for investments leading to a reduction of other emissions in the air, like:

- technologies that reduce air pollution in the technological process; and
- devices for cleaning of flue gases and exhaust air.

Furthermore management and effective waste management, namely:

- systems, equipment and vehicles with Euro 5 engines for the collection, treatment and energy recovery of municipal waste;
- systems and equipment for the collection, treatment, recovery and re-use of waste in technological processes; and
- replacement of asbestos roofing sheets while the thermal insulation of the attic in a facility for the implementation of education, protection of children and adolescents as well as social and health care.

This also applies to the protection of water, including:

- treatment plants for municipal wastewater capacity to 15,000 pe;
- treatment plant for industrial wastewater;
- technologies that reduce water pollution in the technological process and saves potable water; and
- pre-treatment and apparatus for cleaning tainted drinking water sources.

3.10.4. Commercial loans and financing in Slovenia

After the rise of the economic crisis the banks are becoming more demanding by raising the interest rates, demanding excessive guarantees, and making the process more complex and lengthy. This happened despite the security offered by the governmental support scheme which guarantees the feed-in-premium tariffs for 15 years.

The most common characteristics of bank loans are the maximum loan period of 10 years, with six months moratorium on principal.

The guarantees generally required by banks are:

- guarantees from the mother company, the personal liability of the project owner;
- proof from one or more engineering firms declaring the expected turnover and the completion of works within schedule;
- a minimum equity of 35% of the amount borrowed;
- mortgage on the land as security;
- guaranteed feed-in tariffs or daily transfer of receivables;
- partial mortgage on the land;
- an escrow arrangement on a reserve account;
- an APR of six months Euribor plus 4-6%;
- audit by a legal consultant; and
- third party and inherent defects insurance.

Funding conditions have become stricter since 2010 and obtaining financial resources has become difficult.

3.11. Funding options in Sweden

Most small villages and hamlets in Sweden had a saw mill and a corn mill run by hydropower and in Sweden there were also the iron producers, which used the waterfalls to power their hammers and their smithies. It is estimated that Sweden had approximately 25,000 water mills of different kinds and sizes in the early 18th century. Rivers and lakes were also used for floating timber logs to saw mills and paper mills.

In Sweden the major large scale hydropower development took place during the 1940-60's and the major part after the Second World War. Until the 1960's, when Sweden started building nuclear power plants hydroelectric power plants produced almost 100% of the national electrical power. During this period many SHP became less profitable and many were laid dormant.

Today the hydropower plants produce 45–50% (SHPs 4%) of the national electrical power; depending on how much snow and rain that falls. In the far north four of the large Swedish national rivers (Kalix River, Pite River, Torne River and Vindel River) are, due to

strong public protests against further development, protected by a strong environmental legislation.

At present it is very hard to get a permit to restore dormant hydro power plants or even to renovate the ones in use in Sweden, all due to the Swedish interpretation and implementation of the European Water Framework directive (EWFD). Obtaining permits to build a new SHP in a new location is considered to be impossible due to present day politics.

As most SHP owners also own the land as well as the watercourse where the power station is situated, it is fairly easy to get commercial loans for the construction and equipment. The fauna passages normally need other financing as those constrictions are non-profitable.

In order to restore and restart historical mill or renovate working ones the owners have to build fauna passages and the aim of most of the private SCF presented below is to facilitate and finance such instalments.

3.11.1. Examples of RES/micro hydro cooperative projects in Sweden

Cooperatives have been a common organisation form in Sweden for a very long time. Today wind power plants/parks are the most common cooperative projects. In 2011 the Swedish wind power plants cooperatives had close to 25,500 members. It is also common that several individuals own one or more SHP together, in some kind of cooperative, in order to increase the security, strengthen the financing and spread the risks.

3.11.2. ESI Funds for micro hydro in Sweden

The Swedish government is a substantial contributor to the Adaptation Fund, a Strategic Climate Fund that is a financial instrument under the UNFCCC and its Kyoto Protocol (KP) and has been established to finance concrete adaptation projects and programmes in developing country Parties to the KP, in an effort to reduce the adverse effects of climate change facing communities, countries and sectors. On the 24th of May 2013 the Swedish government announced a new pledge to the Adaptation Fund of 15 million USD, making Sweden the biggest donor to the Fund with a total commitment of 59.21 million USD. This, however, does not help the dormant or working micro hydro power plants in Sweden.

The ESI Funds available to Swedish SHPs are to be divided in two different kinds; the one aiming at increasing energy production and the ones aiming at decreasing the problems hydro power production may cause in streams and lakes. The latter ones are not the least important as the constructions and measures needed in order to either restart dormant SHPs or renovate running ones are often expensive and as these measures do not increase the production they are hard to finance by commercial loans.

a) Swedish-Norwegian electricity certificate.

Swedish-Norwegian electricity certificate is a market-based support system for renewable electricity production. The system came into force on the 1st of May 2003 and is intended to increase the production of renewable electricity and also make the production more cost-efficient. The system replaces earlier public grants and subsidy systems.

Since 2012 the Swedish-Norwegian electricity certificate market has delivered a total of 6.2 TWh new renewable energy production. The goal is to reach 26.4 TWh by 2020. The electricity certificate system is a market based system to support producers of renewable energy which was introduced in Sweden in 2003. Since the introduction the electricity certificate system has delivered 18 TWh of renewable energy in Sweden. Wind power constitutes 53% of the increase and biofuel-based electricity production makes up 39%, and SHP makes up for the major part of the remaining 8%.

The electricity certificate system shall contribute to 25 TWh renewable electricity production between 2002 and 2020 in Sweden. In addition 13.2 TWh renewable electricity shall be produced together with Norway between 2012 and 2020.

A new micro hydro power plant is granted electricity certificate for all its production during 15 years.

b) Bixia Environmental Fund (*Bixia Miljöfond*).

Bixia is the fourth biggest energy trade company in Sweden. Each and every month 0.45 SEK of the private costumers of the company fixed charge is transferred to Bixia Environmental Fond. Each year the fond awards about 1 million SEK (106,000 EUR) to different projects aiming towards better climate.

c) Gothenburg Energy DinEl Environmental Fund (*Göteborg Energi DinEl Miljöfond*).

Gotenburg Energy is the leading energy company of Western Sweden. They provide their customers with energy services, broadband, district heating, cooling, natural gas and the electricity supply network. Your Electricity (*Din El*) is the subsidiary energy trade company, and the fifth biggest in Sweden. *Din El* Environmental Fond is funded by 20% of the revenues from costumers buying Local Wind Electricity and Local Water Electricity. Each year approximately 600,000 SEK are awarded to projects contributing to new knowledge or spreading knowledge concerning resilient and sustainable energy systems, with extra focus on renewable energy sources and efficient energy use.

d) Fortums Environmental Fond (*Fortums miljöfond*).

For each kWh Good Environmental Choice-labeled, electricity sold by the company is allocating money to Fortum Environmental Fund. The Fund awards money to projects aiming to diminish the negative environmental effects caused by hydro power production. The projects chosen is approved and evaluated by the Swedish Society for Nature Conservation (SSNC).

e) Good Environmental Choice (*Bra Miljöval*).

The Swedish Society for Nature Conservation (SSNC) started eco-labelling in 1988 on laundry detergent and paper. The SSNC eco-labelling of electricity delivery contracts started at the very beginning of 1996. Both supply and demand of the labelled services are expanding rapidly, also geographically. The same criteria are working in Norway and Denmark in cooperation with SSNC. The labelling of electricity and district heat is a part of the overall energy project of SSNC.

The SSNC Environmental Fund foremost aim is to reduce negative environmental effects caused by hydro power production, such as creating fauna passages, tearing down migration obstacles, and/or taking measures to increase the conditions for endangered species in streams.

3.11.3. Grants and regionals loans in Sweden

a) The County Administrative Board.

The County Administrative Board is the representative of the Government in the region and the coordinating body for State activities in the county.

Every year, the County Administrative Board is allocated funds by the government to be used for different enterprise allowances. These allowances are designed to help the businesses of the county with their long-term profitability and growth.

The scope and direction of the allowances varies between different counties and over time, depending on the resources and specific assignments that the government has issued to counties. We may, as part of the initiatives for regional growth, provide grants for investment, marketing, growth of innovation and training in small and medium-sized businesses. There is also a special allowance for commercial services in rural areas, such as village shops and gas stations.

b) The Board of Agriculture.

The Swedish Board of Agriculture is the one to lead the local development of the Regional fund and the Social Fund, thus in charge of the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund.

c) The LIFE programme.

The LIFE programme will contribute to sustainable development and to the achievement of the objectives and targets of the Europe 2020 Strategy, the 7th Union Environmental Action Programme and other relevant EU environment and climate strategies and plans.

The Environment strand of the new programme covers three priority areas: environment and resource efficiency, nature and biodiversity, and environmental governance and information. The Climate Action strand covers climate change mitigation, climate change adaptation, and climate governance and information.

The programme also consists of a new category of projects, jointly funded integrated projects, which will operate on a large territorial scale. These projects will aim to implement environmental and climate policy and to better integrate such policy aims into other policy areas.

The new regulation also establishes eligibility and the criteria for awards as well as a basis for selecting projects. The programme is open to the participation of third countries and provides for activities outside the EU. It also provides a framework for cooperation with international organisations.

3.11.4. Commercial loans and financing in Sweden

Most commercial banks as well as other financiers in Sweden are positive to, or rather have been, provide loans for investments in hydro power plants. The loan period has been based on a 40 years payback period.

Due to the resent development as the legislation on permits in general and permit period in particular is concerned no one knows what will be in the future; it is up to the Swedish parliament to decide.

3.12. Conclusions and practical recommendations for project developers

For the successful implementation of a SHP cooperative, the following points might be useful and are therefore summarised shortly again here:

- Legal security is of immanent importance for the development of a SHP project. Hence, obtaining detailed information about the site from appropriate authorities in the very beginnings is crucial for realistic decision making.
- In order to avoid dissonances and successive obstacles for the project the planners shall not oversee that for potential stakeholders the chance to participate might change their attitude towards a project in a favourable way. Furthermore, expert knowledge can be easier attracted to support the project if direct participation is offered.
- In case the investments by cooperative members is combined with other financing sources, it is very important to secure the co-financing before trying to sell shares of the project to interested people. Please see the typical information required by banks more detailed in chapter 3.1.4. For additional financing project planners shall moreover gather information about country specific loans. Some of them are presented in the chapters 3.4.-3.11.
- Surplus financing is possible through fund-raising activities. These can be embellished very differently, from crowd funding over charity events to little facilities integrated in the project site like a café or similar.

- In the new funding period from 2014 to 2020 the European Structural and Investment Fund is planning to distribute a minimum share in the ERDF allocation each region in measures supporting the shift to a low-carbon economy: 20% in more developed regions and 15% in transition regions and 12% in less-developed regions. Although it is not yet possible to find out about the share of budgets that will be allocated for small hydro energy projects, the share of budgets for renewable energy funded projects shall be considerably higher in the on-going funding period compared to the previous one.

Chapter 4

Final Remarks

4. Final remarks

This publication has presented key information on permitting; best technical solutions for the refurbishment of water mills and access to funding.

In order to determine where potential small hydropower refurbishment sites are located, an online searchable visual map, the RESTOR Hydro Map, portrays 50,000 sites with information on location, restorability and capacity. Eight countries, namely France, Belgium, Italy, Lithuania, Sweden, Poland, Greece, and Slovenia, based will portray more detailed descriptions about each site.

This detailed information on identified sites will be made available to regional authorities, redevelopment authorities, cooperatives, municipalities, local hydropower developers, interested members of the public and others in order to encourage adoption and refurbishment.

This interactive map is available at this website:

http://www.restor-hydro.eu/en/tools/mills-map/

Nonetheless, one of the main barriers within the RESTOR Hydro project remains the financing aspects. Microhydropower sites, due to their small scale, are all too often considered not profitable enough to be 'bankable'. The solution proposed by the project is to gather several microhydropower sites within one region and to fund the costs through a local cooperative. Local citizens will be offered a share of the project with co-ownership.

From creating a hydropower cooperative model it is hoped that the developers will:

- Increase social acceptance towards hydropower through local community participation.
- Increase local investment in renewable energy generation and provide alternative funding opportunities.
- Reduce administrative difficulties linked to permitting, taxation and operation by consolidating overhead tasks.
- Reduce investment and running costs by maximizing negotiating leverage of small operators for suppliers and electrical consumers.

To support those process further publications and tools have been developed, available on the project website

http://www.restor-hydro.eu/en/tools/community-finance-and-local-cooperatives/

Those include

- A comprehensive business model and basic tools
- A master agreement template, including a review by an attorney from France, Belgium, Italy, Lithuania, Sweden, Poland, Greece, Slovenia and adapted for regional specifics and translated into the respective languages

- A guidebook for the establishment of a cooperative for SHP adapted for regional specifics translated into eight languages (French, Italian, Lithuanian, Swedish, Polish Greek, Flemish and Slovenian)
- Workshops organised in different countries

For more information on the small hydropower cooperatives, please visit http://www.restor-hydro.eu